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SURVIVAL, MOVEMENTS AND HABITAT USE OF APLOMADO FALCONS RELEASED IN SOUTHERN TEXAS

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ABSTRACT.—Aplomado falcons (*Falco femoralis*) formerly bred in Texas, New Mexico, and Arizona. Nesting in the U.S. was last documented in 1952. In 1986, aplomado falcons were listed as endangered and efforts to reestablish them in their former range were begun by releasing captive-reared individuals in southern Texas. From 1993–94, 38 hatch-year falcons were released on Laguna Atascosa National Wildlife Refuge. Two to 3 wk after release, 28 falcons were recaptured for attachment of tail-mounted radio-transmitters. We report on survival, movements, and habitat use of these birds. In 1993 and 1994, four and five mortalities occurred within 2 and 4 wk of release, respectively. From 2–6 mo post-release, 11 male and three female radio-tagged aplomado falcons used a home range of about 739 km^2 (range = 36–281 km^2). Most movements did not extend beyond 10 km from the refuge boundary, but a monitored male dispersed 136 km north when 70 d old. Average linear distance of daily movements was 34 ± 5 (SD) km. After falcons had been released 75 d, they consistently used specific areas to forage and roost. Woody plant density averaged 2.6 plants/ha on forage areas and 3.6 plants/ha at roost sites. Ground surface area was 60% vegetated in foraging areas and 46% vegetated at roost sites.

KEY WORDS: *Aplomado falcon; Falco femoralis; habitat use; mortality; movements; radio telemetry.*

Sobrevivencia, movimientos y uso de hábitat de *Falco femoralis* liberados en el sur de Texas

RESUMEN.—*Falco femoralis* se reproduce en Texas, New Mexico y Arizona. La nidificación en los Estados Unidos fue documentada por última vez en 1952. En 1986, *F. femoralis* fue categorizado como "en peligro"; los esfuerzos por reestablecerlo en sus áreas de reproducción comenzaron por liberación de individuos, criados cautivamente, en el sur de Texas. Desde 1993–94, 38 halcones de un año fueron liberados en Laguna Atascosa National Wildlife Refuge. Dos a tres semanas despues de la liberación, 28 halcones fueron recapturados para montarles un radio-transmisor. Nosotros reportamos sobrevivencia, movimientos y uso de hábitat de estas aves. En 1993, cuatro muertes conocidas ocurrieron a dos semanas de la liberación. En 1994, 5 muertes conocidas ocurrieron durante las cuatro primeras semanas luego de su liberación. De dos a seis meses post-liberación, 11 machos y tres hembras radio-marcadas usaron un ámbito de hogar de alrededor de 73.9 km^2 (rango 36–281 km^2). La mayoría de los movimientos no se extendía más allá de 10 km del borde del refugio, excepto un macho que se dispersó 136 km al norte, luego de 70 d. El promedio de distancias lineares de movimiento diario fue de 34 (SD = 5) km.

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Luego de 75 días de liberados los halcones, ellos en forma consistente usaron áreas específicas para forrajear y descansar. La densidad promedio de plantas leñosas fue de 2.6 plantas/ha en áreas de forrajeo y de 3.6 plantas/ha en sitios de descanso. La cobertura vegetal fue de un 60% en áreas de forrajeo y de un 46% en sitios de descanso.

[Traducción de Ivan Lazo]

The distribution of the aplomado falcon (*Falco femoralis*) in the U.S. formerly extended from southern Arizona and New Mexico to westcentral and southern Texas (Sprunt 1955, AOU 1983). Specimen records and documented sightings indicate they were fairly common throughout their range until about 1940 but rarely seen thereafter (Hector 1987). Nesting in the U.S. was last documented in 1952 near Deming, New Mexico (Ligon 1961). Reasons for the decline of the aplomado falcon are unknown, but habitat alteration by encroachment of woody brush species in former grasslands, and later widespread use of hydrocarbon pesticides such as DDT, appear to have been major contributors of the decline (Hector 1987). Severe pesticide contamination in eastern Mexico and evidence of population declines in northern Mexico (Kiff et al. 1980) led to the species being listed as endangered in 1986 (Shull 1986).

Failure of aplomado falcons to recolonize their former range prompted the U.S. Fish and Wildlife Service (USFWS) to implement the reintroduction phase of the Aplomado Falcon Recovery Plan in southern Texas (U.S. Fish and Wildlife Service 1990). This region was chosen as most suitable for releases, because it appears to have been the area where aplomado falcons last occurred in high breeding densities in the U.S.(Hector 1987, 1990) and because it is near remnant populations in Mexico.

From 1986–89, Peregrine Fund, Inc. personnel released 22 aplomado falcons on or in the vicinity of Laguna Atascosa National Wildlife Refuge (LANWR; Cade et al. 1991). Outcomes of these releases are unknown because birds were not monitored beyond 2 mo post-release. Herein, we report the survival, movements, and habitat use of aplomado falcons released in 1993 and 1994.

STUDY AREA AND METHODS

LANWR is an 18 268 ha Gulf of Mexico coastal refuge located about 32 km north of Brownsville, Texas. The refuge was established in 1946, primarily for the protection of wintering waterfowl. Management priorities now include protection of endangered species. The refuge slopes toward the Laguna Madre about 27 cm/km. Elevations of 6–10 m occur on natural clay/sand ridges, but

the majority of the refuge is <2 m above sea level. The landscape consists of an irregular pattern of meandering oxbow lakes, brushy clay ridges, coastal salt/tidal flats, and impoundments (USFWS unpubl. rep.).

Natural vegetation on the refuge is a complex mixture of temperate, semiarid, tropical, and seashore species whose distribution is primarily determined by elevation. Six general vegetative types occur on the refuge: marshy wetland (8296 ha), coastal prairie (5666 ha), thorn scrub (3237 ha), savannah (202 ha), grassland (445 ha), and cropland (421 ha) (USFWS unpubl. rep.).

Monitored aplomado falcons were captive-bred and raised at the Peregrine Fund, Inc., Boise, Idaho. When about 4 wk of age, young falcons were transported to LANWR. Release boxes were opened and fledglings were released when about 37 d old. Food was provided at the release site until released falcons no longer returned to feed.

Two to 3 wk following release, 21 of 26 falcons released in 1993, and seven of 12 released in 1994 were recaptured for attachment of tail-mounted radiotransmitters. Transmitters weighing 4 g with a battery life of 4–6 mo were attached to males and some females, while radios weighing 5 g and lasting 11 mo were used only on female falcons. Reception distances were ≤1.6 km on ground and 6–10 km from aircraft. Telemetric monitoring was primarily accomplished from the ground, but aerial searches were conducted when ground efforts failed to locate falcons for at least 3 d.

Locations were derived from a minimum of two bearings using the strongest signal method as described by Springer (1979). Locations estimated from radio bearings and sightings were used to construct minimum convex polygons (Jennrich and Turner 1969). Range size was estimated using the Microcomputer Program for Analysis of Animal Locations (Stüwe and Blohowiak 1985).

We used the point-centered quarter method (Cottam and Curtis 1956) to describe woody vegetation structure and density, and a modified version of the step-point method (Evans and Love 1957) to estimate ground cover and botanical composition on foraging areas and roosting sites used by released falcons. Areas were categorized as foraging areas if we observed recurrent foraging by ≥1 falcons for >2 wk. Roost sites were defined as areas where ≥1 falcons roosted ≥3 times.

Woody vegetation was sampled at seven forage areas and two roost sites. Five forage areas and the two roost sites were on LANWR; the remaining two forage areas were within 2 km of the western and southern boundaries of the refuge. Woody vegetation transects were centered on frequently used perch or roost sites. From this center point, three linear transects were established that radiated outward 300 m. Initial transects were selected randomly and each succeeding transect was placed 120° on either side of the initial transect. Sampling points were at the site center, 100 m, and 200 m. Four 90° sam-

Table 1. Sex, date released, number of locations, range size and number of days monitored for radio-tagged aplomado falcons released on Laguna Atascosa National Wildlife Refuge during 1933 and 1994.[a]

SEX	DATE RELEASED	NUMBER OF LOCATIONS	RANGE SIZE (km²)[b]	DAYS MONITORED
M	1 Aug 93	18	49.6	83
F	13 Jun 93	23	215.5	149
M	13 Jun 93	31	59.3	173
M	7 Jul 93	13	79.6	132
M	7 Jul 93	11	67.1	103
M	14 Jul 93	19	164.8	86
F	2 Jul 93	10	35.7	112
M	11 Jul 93	24	78.1	89
M	11 Jul 93	12	64.8	66
M	1 Aug 93	11	86.5	42
M	25 Jul 93	18	46.2	100
M	25 Jul 93	11	55.8	286
F	19 Jul 94	34	277.2	59
M	15 Jun 94	28	281.2	61

[a] Individuals monitored for a ≥2 mon and ≥10 telemetric and/ or visual locations.

[b] Ranges derived from minimum convex polygons.

pling quadrants were established at each sampling point with the transect line and a line perpendicular to the transect forming the borders of the quadrant. Woody plants ≥0.5 m tall nearest the sampling point in each quadrant were selected. From these plants, sampling point-to-plant distance, total height, crown width at narrowest and widest points, and species were recorded. Density of woody vegetation was determined following formulas in Bonham (1989).

The same transects established for the quarter method were used for step-point sampling. Sampling points were approximately 1 m paces along transects. Any plant touching the boot or within 1 cm in front of the boot was considered a hit for recording plant species, otherwise bare ground, bare ground with standing water, plant litter or plant litter with standing water was recorded.

Chi-square tests were used to test for intrasite and intersite variability in vegetation. Habitat tabulation and statistical testing were done using SAS (SAS Institute, Inc. 1987). Means are accompanied by standard errors and statistical significance was at $\alpha = 0.05$.

RESULTS

Survival. Within 2 wk of release in 1993, we found remains of four falcons. No other mortalities were documented in 1993, giving a minimum of 15% mortality for the first year. In 1994, five known mortalities occurred during the first 4 wk post-release giving a minimum mortality rate of 42%. Five falcons that roosted on exposed, elevated perches were suspected
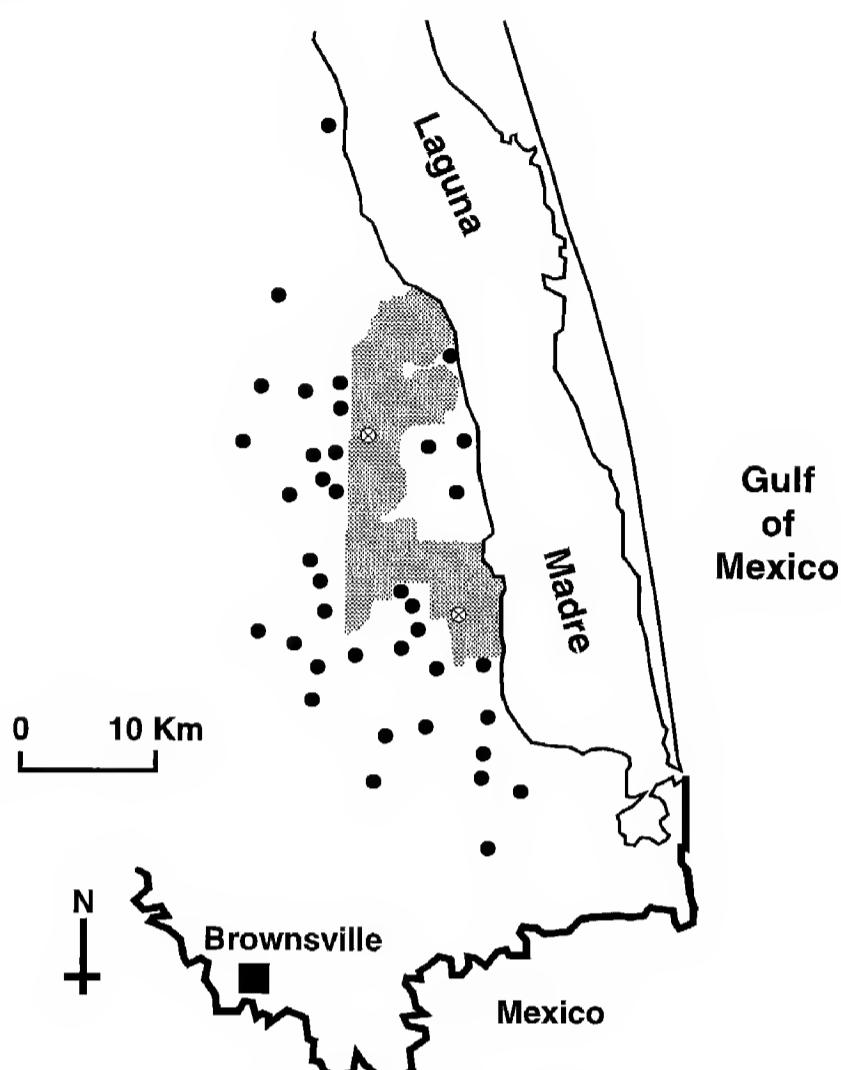
Figure 1. Locations of 28 aplomado falcons recorded 6 mo following releases in 1993 and 1994 at Laguna Atascosa National Wildlife Refuge, Texas. Release sites are marked within the refuge boundary.

of being preyed on by great horned owls (Bubo virginianus). Three falcons that consistently roosted on open ground were probably preyed on by coyotes (Canis latrans). A Harris' hawk (Parabuteo unicinctus) captured one falcon. Ten of the released falcons could not be located 3 mo post-release and the status of these individuals was unknown. The period from release to last known location for these 10 averaged 53.5 ± 6.1 d.

Movements. We recorded 10–34 telemetric or visual locations on 14 falcons (11 males, 3 females) that were monitored 42–286 days (Table 1). Locations resulted from aerial searches as far as 300 km north, 80 km inland, and 27 km south of the refuge. The average number of locations for each falcon was 19 ± 2. Range sizes averaged 112 ± 23 km² with ranges of males averaging 94 ± 21 km² and those of females averaging 176 ± 72 km². Total area used was 739 km², and included land on and in the vicinity of LANWR (Fig. 1). Number of locations and range size were correlated ($r = 0.66$, df = 1, $P < 0.05$).

Table 2. Measurements (m) of woody vegetation in foraging and roost sites of aplomado falcons released on LANWR in 1993 and 1994.

| SITE TYPE | CONFIDENCE INTERVAL FOR MEAN DENSITY (95%) | WOODY PLANT DENSITY[a] | MEAN POINT TO PLANT DISTANCE | CONFIDENCE INTERVAL FOR MEAN DISTANCE (95%) | PLANT HEIGHT $\bar{x} \pm$ SE | CROWN | |
						LENGTH $\bar{x} \pm$ SE	WIDTH $\bar{x} \pm$ SE
F[b]	0.3–1.6	0.6	130.6	79.6–181.6	1.2 ± 0.1	1.3 ± 0.1	1.4 ± 0.1
F	0.3–0.9	0.5	144.8	105.2–184.3	1.6 ± 0.2	1.5 ± 0.3	1.6 ± 0.3
F	31.2–244.1	67.8	12.1	6.4–17.9	0.8 ± 0.1	0.6 ± 0.1	0.8 ± 0.1
F	3.2–17.8	6.3	39.7	23.7–55.8	0.9 ± 0.2	1.3 ± 0.2	1.3 ± 0.2
F	1.7–6.9	3.1	57.0	38.0–76.1	1.2 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
F	28.9–918.3	83.8	10.9	3.3–18.6	0.8 ± 0.0	1.0 ± 0.1	1.2 ± 0.1
F	4.21–33.8	9.2	33.0	17.2–48.7	0.8 ± 0.0	0.6 ± 0.1	0.7 ± 0.1
R	6.7–55.7	14.9	25.9	13.4–38.5	1.6 ± 0.1	1.7 ± 0.3	1.6 ± 0.2
R	0.7–5.3	1.6	79.7	43.3–116.1	1.5 ± 0.1	1.2 ± 0.1	1.4 ± 0.1

[a] Plants/ha.
[b] F = forage; R = roost.

For the first few weeks after release, falcons stayed close to their release towers. By 35 d post-release, falcons at a release site in 1993 began traveling to the other release site 15 km away. By 68 d post-release, at least seven falcons had travelled between the two release sites. In 1994, only two females (73 and 91 days of age) moved between the release sites. Approximately 2.5 mo post-release, falcons began ranging to several kilometers from the refuge boundary. One 70-d-old male falcon was observed 136 km north of LANWR after roosting on the refuge 2 d earlier. A second male flew 14 km west of the refuge in an apparent dispersal when 70 d old, but returned to the refuge frequently. Most outbound movements from LANWR were <10 km for 2–6 mo post-release (Fig. 1).

Mean daily linear travel distances from roost to roost for monitored birds was 34 ± 5 km. From first light, one male falcon was tracked for 55 km to its evening roost, but we do not know if it had roosted there the previous night.

Habitat Use. Approximately 75 d post-release, falcons (N = 23) began consistently using specific areas to forage and roost. All sampled roost sites were within 2 km of foraging areas, and consistently in honey mesquite (*Prosopis glandulosa*) stands on edges of open, usually grassy areas. Most foraging areas contained small honey mesquites and trecul yuccas (*Yucca treculeana*) on higher elevations overlooking saltflats or wet marshy areas in depressions known locally as "charcos." Less often used foraging sites were cattle-grazed pastures, characterized by low grasses (<60 cm), scattered prickly-pear (*Opuntia lindheimeri*), and live and dead honey mesquite trees. Infrequently used foraging areas were bare ground and fallow agricultural fields in the vicinity of LANWR. Most fallow or plowed fields were typically surrounded by grassy areas. In these open environments, falcons landed on the ground or used posts or honey mesquites as perches.

The mean overall point-to-plant distance in foraging areas was 61.4 ± 20.7 m resulting in a density of 2.6 woody plants/ha (Table 2). Plants in foraging areas had a mean height of 1.1 ± 0.1 m and mean crown dimensions of 1.1 ± 0.1 by 1.2 ± 0.1 m. Overall point-to-plant distances for roost sites averaged 52.8 ± 22.4 m or 3.6 woody plants/ha (Table 2). Plants at roost sites had a mean height of 1.5 ± 0.1 m and mean crown dimensions of 1.4 ± 0.1 by 1.5 ± 0.1 m.

In foraging areas, honey mesquite, sea oxeye (*Borrichia frutescens*), and prickly-pear comprised 83% of the total sampled woody plant vegetation (Table 3). Overall heights of woody plants in foraging areas ranged from 0.5–5.0 m. In roost sites, honey mesquite, huisache (*Acacia smallii*), and trecul yucca comprised 89% of the total sampled woody plant vegetation (Table 3). Overall heights of woody vegetation in roost sites ranged from 0.8–3.4 m. Honey mesquite, which was the most abundant woody species on both site types, averaged 1.4 ± 0.1 m tall in forage areas and 1.6 ± 0.2 m tall in roost sites. Second and third most abundant woody plant species averaged from 0.7–0.9 m taller in roost sites than in foraging areas.

Table 3. Relative frequency and heights of most abundant woody plants in foraging and roost sites of aplomado falcons released on Laguna Atascosa National Wildlife Refuge in 1993 and 1994.

SITE TYPE[a]	SPECIES	RELATIVE FREQUENCY (%)	HEIGHT $\bar{x} \pm$ SE (m)	RANGE (m)
F	*Prosopis glandulosa*	38.5	1.4 ± 0.1	0.5–5.0
F	*Borrichia frutescens*	31.8	0.6 ± 0.0	0.5–1.0
F	*Opuntia lindheimeri*	12.5	0.8 ± 0.0	0.5–1.4
R	*Prosopis glandulosa*	44.6	1.6 ± 0.2	0.8–3.4
R	*Acacia smallii*	26.8	1.5 ± 0.1	1.0–2.5
R	*Yucca treculeana*	17.9	1.5 ± 0.2	1.0–2.6

[a] F = forage, R = roost.

Foraging sites averaged 60.2 ± 5% vegetated and 39.8 ± 5% nonvegetated (Table 4). We identified 48 (range = 7–26) species of woody plants, shrubs, halophytes, and grasses on forage areas (Perez 1995). Five species made up 46.7% of the plants. Plant cover on forage areas ranged from 42.0–75.7%, while wet and dry bare ground ranged from 14.9–43.3%, and wet and dry plant litter ranged from 2.4–41.8%.

Roost sites averaged 46 ± 9% vegetated and 54 ± 9% nonvegetated surface area (Table 4). We identified 20 (range = 15–17) species on roost sites (Perez 1995). Four species comprised 39.3% of the vegetation in roost sites. Plant cover in roost sites ranged from 37.0–55.1%, while wet and dry bare ground ranged from 4.5–58.5% and wet and dry plant litter ranged from 22.0–58.5%. Variability of nonvegetated surface area differed among forage areas (χ^2 = 410.91, df = 6, P < 0.05) and among roost sites ($\chi 2$ = 60.15, df = 1, P < 0.05). Variability between both site types also differed significantly (χ^2 = 115.58, df = 1, P < 0.05).

DISCUSSION

Survival. We recorded a 24% mortality rate for released hatch-year aplomado falcons at LANWR during the first 4 wk post-release. All but one of the deaths appeared to occur during hours of darkness. During the first few weeks after release, some young falcons were seen roosting on the ground or conspicuously on the tops of the release towers or fence posts where they probably became easy prey for great horned owls and coyotes. Great horned owl predation is the greatest known cause

Table 4. Ground cover on forage areas and roost sites used by aplomado falcons released on Laguna Atascosa National Wildlife Refuge in 1993 and 1994.

FORAGE AREAS	COVER (%)	ROOST SITES	COVER (%)
Vegetated		Vegetated	
Monanthochole littoralis	27.0	*Spartina spartinae*	20.4
Sporobolus virginicus	7.2	*Monanthochole littoralis*	11.2
Dichanthium aristatum	5.8	*Prosopis glandulosa*	5.1
Batis maritima	5.1	*Salicornia virginica*	2.6
Chloris gayana	1.6	Other species[b]	6.7
Other species[a]	13.5		
Nonvegetated		Nonvegetated	
Bare ground	21.7	Bare ground	13.6
Plant litter	12.6	Plant litter	40.2
Bare ground with water	5.3	Bare ground with water	0.1
Plant litter with water	0.2	Plant litter with water	0.1

[a] Other species at <1% each (N = 43).
[b] Other species at <1% each (N = 16).

of post-fledgling mortality of peregrine falcons (*Falco peregrinus*) released in reintroduction programs in the eastern U.S. (Sherrod 1983). Sherrod (1983) also noted that released peregrine falcons do not have the benefit of parental defense, which would be expected to reduce young falcon deaths.

Movements. Hector (1990) predicted home range size for aplomado falcons to be 34 km²/pair. Montoya (1995) monitored paired wild adult and subadult aplomado falcons in Chihuahua, Mexico, from February–August 1993, and found ranges of only <1–21 km². Our ranges of 36–281 km² were larger than predicted and were probably due to the fact that post-fledgling falcons have expanded territories before they establish pair bonds.

Daily linear movements of up to 55 km that we recorded showed the highly mobile behavior of young aplomado falcons. This high mobility and relatively short signal range of our transmitters made it difficult to account for the whereabouts of radio-tagged falcons. We frequently could not locate radio-tagged birds from the time they left roost sites in the morning until they returned that evening. As a result, actual home ranges were probably larger than recorded ranges.

There was great variability among individuals in dispersal distances. At least six aplomado falcons were still in the general vicinity of the refuge 6 mo after release and one remained near the release site for >1 yr post-release. Yet, other falcons dispersed 14–136 km.

Long range dispersals have been recorded previously for released aplomado falcons. A banded aplomado falcon was reported at Falfurrias, Texas, 140 km NW of LANWR (Lasley and Sexton 1992). This bird may have been released at LANWR, or may have been released in 1985 in Kleberg County, Texas, 15 km east of Falfurrias. A male released in 1989 at LANWR dispersed south to the port of Brownsville, about 22 km away (Peregrine Fund unpubl. rep.). Similar data for released peregrine falcons showed dispersal occurred at an average age of 76 d for males and 80 d for females (Sherrod 1983). Typical aplomado falcon movements were difficult to categorize as dispersal because permanent 1-way movements were rarely documented during the entire monitoring period. However, we may not have monitored enough released birds to effectively document dispersal, because only 37% of the falcons released during both seasons were monitored for >2 mo.

Age of dispersal may have been influenced in our study by release methodology. Food was provided at the release site until released falcons no longer returned to feed. Feeding may delay dispersal from the area, but is thought to be necessary until falcons become proficient hunters. Abundance of local food supplies was previously shown to delay the need to disperse; Johnson (1981) noted tundra nesting raptors gather in areas of high lemming (*Lemus lemus*) density, but rapidly disperse once prey populations decline. In addition, LANWR received 42 cm of rainfall above normal in 1993, which appeared to promote an eruption of dragonflies (Aeschnidae). We observed young aplomado falcons foraging almost exclusively on dragonflies while they were abundant. Such responses to prey abundance have been previously noted for white-tailed kites (*Elanus caeruleus*), ferruginous hawks (*Buteo regalis*), and rough-legged hawks (*Buteo lagopus*) (Johnson 1981).

Habitat Use. According to The Aplomado Falcon Recovery Plan (U.S. Fish and Wildlife Service 1990), suitable habitat contains inter-tree distances of from 15–45 m with a mean of 30 m and a woody plant density of 19 trees/40 ha or about 0.48 plants/ha. We found inter-plant spacing of woody vegetation to average 61 m in foraging areas and 53 m in roost sites, which exceeded the upper limit in the recovery plan. Hector (1986) reported inter-plant distances of 18–103 m on nesting territories in coastal Mexico, and Montoya (1995) recorded point-to-plant distances on nesting territories in desert grasslands of northern Chihuahua from 9–30 m. We found woody plant densities ranging from 0.5–83.8 plants/ha in foraging areas and 1.6–14.9 plants/ha in roost sites. Woody plant density on the Chihuahuan sites ranged from 11–140 plants/ha with a mean of 77 plants/ha (Montoya 1995). This suggested that aplomado falcons use a broader range of woody plant density than previously thought or may be occupying suboptimal habitat.

Caution must be used in comparing woody plant densities across studies because the criteria for sampling differ according to individual site assessments, life stages, and geographic differences. For example, Hector (1981, 1986) included woody plants with a diameter at breast height >2 cm and log transformed his data to a form which assumed a more normal distribution. Our study and Montoya (1995) may be more comparable because methods and criteria were basically identical. However, life stages of falcons differed between Montoya's and our studies; Montoya studied a wild pop-

ulation of paired falcons, while we studied post-fledgling released falcons.

Plant cover in foraging and roosting areas was quite variable. Plant cover variation occurring within sites was usually due to intergradations of salt-flats and grasslands or wooded areas, resulting from subtle elevational differences along transects. In addition, these elevational changes resulted in different plant assemblages at each site. For example, gulf cordgrass, a species that often forms a transitional zone between wetland and upland areas (Lazarine 1988), was the most abundant plant in roosting areas, while foraging sites were dominated by keygrass (*Monanthochloe littoralis*), a species that is found only in tidal flats or salt marshes and attains a maximum height of 8–15 cm (Lonard 1993).

In foraging areas, 47% of the vegetation grew <80 cm tall and 22% of the ground surface was bare. The structural influences of ground level vegetation on habitat selection has been noted for many raptors (Janes 1985). Aplomado falcons tend to be perch foragers (Johnsgard 1990). According to Sprunt (1955), aplomado falcons generally use lower perches and often alight on the ground. We recorded many incidental feeding observations from perched positions on fence posts, yuccas, or on the ground. As the vegetation becomes taller and denser, perch foraging becomes less feasible (Janes 1985). Thiollay (1980) found that patches of short grass were strongly selected for by grassland raptors (including aplomado falcons) in eastern Mexico. He further hypothesized height of grass cover was an important factor in determining profitability of sit-and-wait (perch) feeding methods or hunting flight.

One goal of monitoring released aplomado falcons was to evaluate effectiveness of the release effort. Fourteen falcons survived for 2 mo and seven for ≥100 d. Most released falcons used more diverse habitats than predicted while staying on or near the refuge. Based on these results, we think the release program is showing evidence of success.

ACKNOWLEDGMENTS

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RESULTS OF A RAPTOR SURVEY IN SOUTHWESTERN NEW MEXICO

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ABSTRACT.—Eight roadside surveys for raptors were conducted in southwestern New Mexico from May 1988–January 1989 to examine seasonal abundance and habitat use. Of the 17 species observed, American kestrels (*Falco sparverius*), red-tailed hawks (*Buteo jamaicensis*), turkey vultures (*Cathartes aura*), and northern harriers (*Circus cyaneus*) were most common and occurred along the entire survey route in all habitats. Bald eagles (*Haliaeetus leucocephalus*) were recorded less frequently only in January in riparian habitats and pinyon-juniper and Ponderosa pine ecotones, and Swainson's hawks (*B. swainsoni*) were infrequently observed in mesquite grasslands and Chihuahuan desertscrub in May and July. Golden eagles (*Aquila chrysaetos*), ferruginous hawks (*B. regalis*), prairie falcons (*F. mexicanus*), and Cooper's hawks (*Accipiter cooperii*) were also recorded infrequently but occurred widespread along the survey route.

KEY WORDS: *southwestern New Mexico, distribution, relative abundance, habitat use, raptor roadside survey.*

Resultados de rutas de estudio de rapaces en el suroeste de New Mexico

RESUMEN.—Ocho estudios de ruta para rapaces fueron ejecutados en el suroeste de New Mexico desde mayo de 1988 a enero de 1989, con el fin de examinar abundancia estacional y uso de hábitat. De las 17 especies observadas, *Falco sparverius*, *Buteo jamaicensis*, *Cathartes aura* y *Circus cyaneus* fueron las más comunes con presencia a lo largo de todas las rutas y hábitats. *Haliaeetus leucocephalus*, fue registrada con menor frecuencia solamente en diciembre y en ciertos hábitat y *Buteo swainsoni* fue poco observado en praderas en mayo y julio. *Aquila chrysaetos*, *Buteo regalis*, *Falco mexicanus* y *Accipiter cooperii* fueron registrados infrecuentemente pero se presentaban muy dispersos a lo largo de la ruta de estudio.

[Traducción de Ivan Lazo]

El Paso Electric Company initiated construction of the Arizona Interconnection Project (AIP), a 345 kv transmission line between Deming and Red Hill, New Mexico in 1988. As part of the environ-mental review process, we conducted eight raptor surveys along roads parallel to or near the transmission line right-of-way (ROW). Our objectives were to: (1) compile a species list, (2) determine the distribution of raptors along the transmission line ROW, (3) document habitat use by raptors, and (4) estimate the relative abundance of raptor species observed.

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STUDY AREA AND METHODS

The AIP crosses seven major biotic communities or biomes between Red Hill and Deming (Fig. 1). Nearly 80% of the area traversed is grassland or desertscrub (Table 1). We followed the classification system described by Brown (1982) to determine habitat types along the survey route, and Brown and Lowe (1983) to further identify habitat types traversed during our surveys.

The survey route we selected provided access along many portions of the AIP ROW and crossed habitats representative of those crossed by the AIP where access was limited. The route followed improved and unimproved surface roads, as well as the AIP corridor whenever possible. The length of the route was approximately 515 km, whereas the length of the AIP corridor was approximately 419 km.

Surveys along the route were scheduled in May 1988 to coincide with nesting, in July 1988 to coincide with fledging, in October 1988 to coincide with fall migration, and in January 1989 to coincide with wintering. Each seasonal survey was conducted by two teams of two observers each. One team began at Red Hill in the north and the other near Deming in the south. Each team surveyed the entire route by vehicle over a 5–6 d period, simultaneously and independently of the other team. For example, Surveys 1 and 2 were conducted concurrently from 2–7 May 1988, Surveys 3 and 4 from 11–15 July 1988, Surveys 5 and 6 from 26–30 October 1988, and Surveys 7 and 8 from 24–28 January 1989. Surveys were conducted during variable weather conditions, but were always terminated during periods of precipitation (rain or snow).

Each survey team drove the route at 17–40 km/hr. When raptors were observed, vehicles were stopped momentarily to identify the birds. Periodic stops were also made to scan for distant raptors. All raptor observations were recorded on data forms and mapped. Data recorded for each observation included date, time, location, species, age, sex, number, habitat, activity, and perching substrate, if applicable. Weather conditions and vehicle mileage were also recorded. Surveys were initiated between 0600–0900 H Mountain Standard Time (MST) and were terminated between 1600–1900 H MST.

The survey route was treated as a line transect to estimate the relative abundance of each species of raptor. Line transects are considered to be one of the best techniques for estimating raptor relative abundance (Fuller and Mosher 1987). We used the index of relative abundance developed by Woffinden and Murphy (1977) for diurnal raptors in the eastern Great Basin of Utah that is based on km traveled during roadside surveys. The index is calculated as follows:

Relative Abundance

$$= \frac{\text{Number of species observed}}{\text{Number of km traveled}} \times 1000$$

To examine seasonal differences, we pooled the data from Surveys 1–4 to calculate a Spring/Summer relative abundance index and the data from Surveys 5–8 to calculate a Fall/Winter index.

RESULTS AND DISCUSSION

Of the 43 raptor species found in New Mexico, 29 are falconiforms and 14 are strigiforms (Glinski et al. 1988). We observed 17 of the falconiform species during our surveys. Interestingly, Kimsey and Conley (1988) observed only 11 species in their 4-yr study of raptor habitat use near Las Cruces, slightly southwest of our study area.

Plains grassland accounted for the largest percentage of habitat crossed by the AIP, approximately 30% (Table 1). This cold temperate plant community is characterized by essentially open landscapes of either sod-forming short grasses or tall grass species. American kestrels (*Falco sparverius*), red-tailed hawks (*Buteo jamaicensis*), and northern harriers (*Circus cyaneus*) were the most frequently observed species, followed by prairie falcons (*F. mexicanus*), ferruginous hawks (*B. regalis*), and turkey vultures (*Cathartes aura*) (Table 2). Golden eagles (*Aquila chrysaetos*) and merlins (*F. columbarius*) were infrequently observed. Nearly all of the sightings of northern harriers in grasslands were in October and January, indicating that plains grassland habitat may be important to migratory and wintering populations of this species (Table 3).

Semidesert grassland accounted for the second largest percentage of habitat crossed by the AIP ROW (26%, Table 1). This warm temperate grassland community, sometimes called "mesquite grassland," is a highly diverse assemblage of perennial bunch grasses, woody perennial shrubs, leaf succulents, and cacti. Large numbers of several species were observed in these grasslands during all seasons (Tables 2, 3). American kestrels and red-tailed hawks were recorded during every survey while turkey vultures and Swainson's hawks (*B. swainsoni*) were observed only in May and July and golden eagles only in July, October, and January. Northern harriers and prairie falcons were commonly seen, especially in October and January. Other fall and winter observations included ferruginous hawks, rough-legged hawks (*B. lagopus*), and merlins (Table 3).

Chihuahuan desertscrub accounted for approximately 23% of the habitat crossed by the AIP ROW (Table 1). This warm temperate vegetation type is frequently characterized by creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), mesquite (*Prosopis spp.*), and other shrubs. Large numbers of several species were recorded in these habitats during all seasons (Table 2). Turkey vultures and
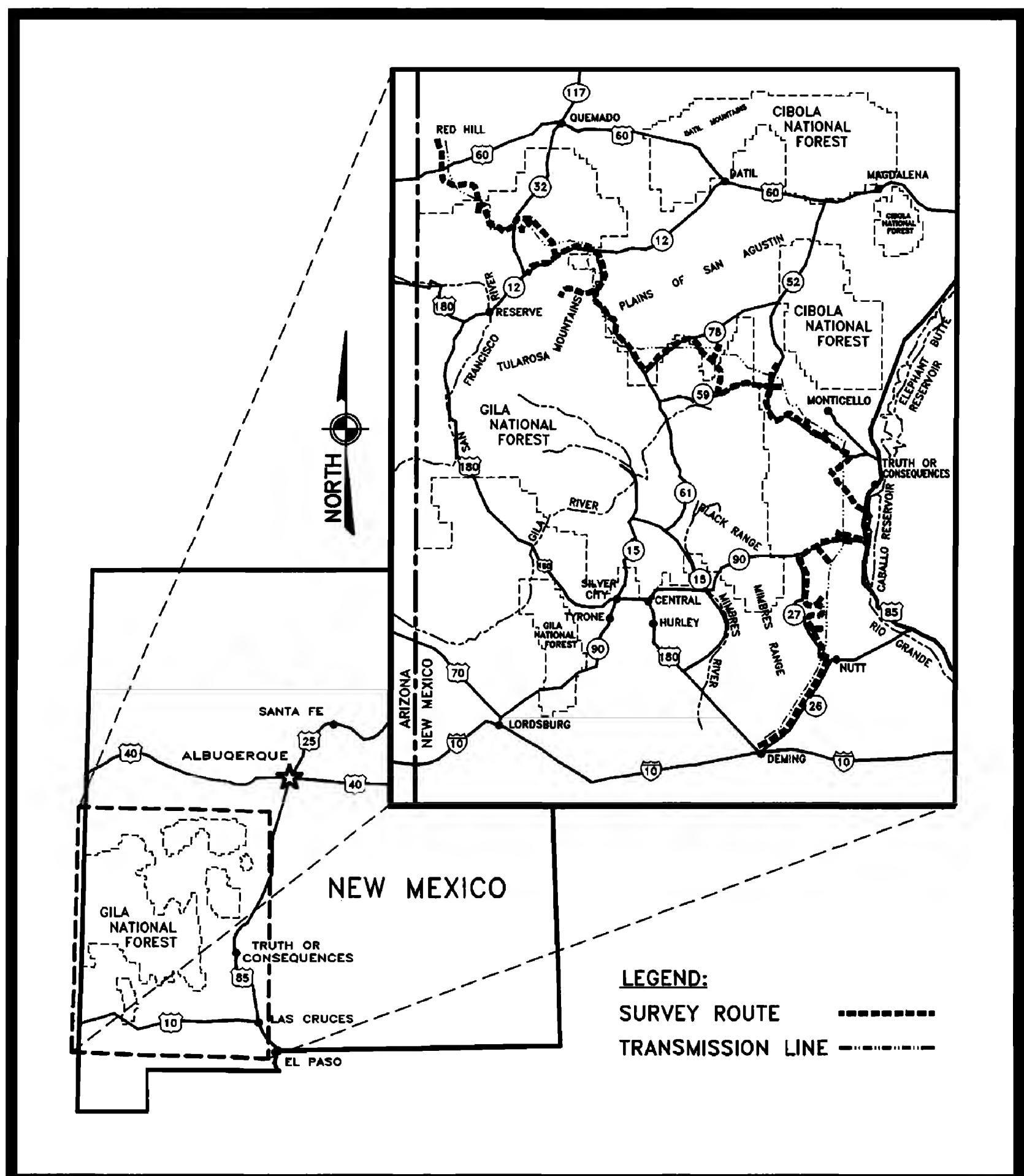
Figure 1.   Raptor survey route along the AIP corridor in southwestern New Mexico, 1988–89.

Swainson's hawks were observed in May and July, red-tailed hawks and American kestrels from May to January, golden eagles and prairie falcons from July to January, and northern harriers and ferruginous hawks in October and January (Table 3).

Great Basin conifer woodland accounted for approximately 12% of the habitat crossed by the AIP ROW (Table 1). This cold temperate, dry, mid-elevational biome, often referred to as pinyon-juniper woodland, is dominated by junipers (primarily *Ju-*

Table 1. Habitats along the AIP transmission line right-of-way. Habitat types follow Brown (1982).

HABITAT TYPE	LENGTH (km)	% AIP
Plains grassland	125.6	30.0
Semidesert grassland	109.5	26.2
Chihuahuan desertscrub	96.6	23.1
Great Basin conifer woodland	49.9	11.9
Pinyon-juniper/ponderosa pine eco-tone	17.7	4.2
Rocky Mountain montane conifer forest (ponderosa pine)	8.1	1.9
Rocky Mountain montane conifer forest (mixed)	8.1	1.9
Riparian deciduous woodland	1.6	0.4
Rocky Mountain montane grassland	1.6	0.4
Total	418.7	100.0

niperus monosperma) and pinyon pines (*Pinus edulis*). Red-tailed hawks and American kestrels were the most frequently observed species (78% of total observations), but turkey vultures were also frequently observed (Table 2). At the ecotone where this community met plains grasslands, raptors were particularly abundant. In October and January, golden eagles, ferruginous hawks, and rough-legged hawks were commonly observed at this ecotone. Pinyon-juniper woodlands also came into contact with semidesert grasslands along the AIP ROW. At this ecotone, golden eagles were observed in July, while bald eagles (*Haliaeetus leucocephalus*) were observed in pinyon-juniper and Ponderosa pine (*P. ponderosa*) ecotones in January (Tables 2, 3).

Rocky Mountain montane conifer forest accounted for approximately 2% of the habitat crossed by the AIP ROW (Table 1). This cold temperate community is generally found above 2,250 m and is dominated by ponderosa pine with lesser areas of mixed conifer forests of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), white pine (*P. flexilis*), or aspen (*Populus tremuloides*). Red-tailed hawks and American kestrels were the most frequently observed raptors in these forest habitats (Table 2). Several unidentified accipiters, including an adult northern goshawk (*A. gentilis*), were observed in a potential nesting area. In January, several bald eagles were observed in areas of forest-plains grassland ecotones. These parklands, or montane grasslands, are scattered throughout the

northern portion of the AIP ROW (Fig. 1, Table 2).

The AIP crossed several large drainages supporting riparian deciduous forest and woodland communities, particularly Animas and Palomas creeks near Truth or Consequences (Fig. 1). Several species were observed or heard in these drainages, including Cooper's hawks (*A. cooperii*), sharp-shinned hawks (*A. striatus*), red-tailed hawks, and American kestrels (Table 2). Riparian habitats along the northern portion of the survey route included the Tularosa River and Apache Creek, where American kestrels, red-tailed hawks, ferruginous hawks, and bald eagles were observed. Bald eagles were also observed along the shoreline of Caballo Reservoir in January.

In addition to native habitats surveyed along and near the AIP ROW, agricultural and urban areas were also traversed along the survey route. Red-tailed hawks and American kestrels were the most frequently observed species in these habitats, but turkey vultures, Swainson's hawks, northern harriers, ferruginous hawks, merlins, and rough-legged hawks were also seen (Table 2).

The overwhelming number of American kestrels and red-tailed hawks observed during all surveys and all seasons indicated they were the most abundant raptors in the region. Their combined observations accounted for over 60% of individuals observed (Table 3). Kimsey and Conley (1988) also found American kestrels and red-tailed hawks to be the most abundant species in their study area in southcentral New Mexico. We also found Swainson's hawks, northern harriers, golden eagles, ferruginous hawks, and Cooper's hawks in approximately the same relative abundances. The most notable difference between the two surveys was that no turkey vultures were recorded during their 4-yr study in southcentral New Mexico. This difference could partially be explained because, unlike our survey, the previous survey excluded the months of June and July.

We also observed more red-tailed hawks in the fall and winter (70%), while more American kestrels were observed in the spring and summer (76%). This suggests that large numbers of red-tailed hawks overwinter in the area, augmenting the resident population as reported by Hubbard et al. (1988), and that most of the breeding kestrels migrated further south for the winter. Other species which overwintered in the study area, as shown by increased observations in October and January,

Table 2. Numbers of raptors observed in habitat types included in the AIP surveys, 1988–89.

SPECIES	HABITAT TYPE[a]						
	PP[a]	PJ	PG	SDG	CD	R	A/U
Turkey vulture (Cathartes aura)	6	34	12	50	74	20	7
Golden eagle (Aquila chrysaetos)	3	14	9	34	30	2	
Bald eagle (Haliaeetus leucocephalus)	7	2				16	
White-tailed kite (Elanus caeruleus)		1					
Northern harrier (Circus cyaneus)	1	5	41	63	47	3	4
Sharp-shinned hawk (Accipiter striatus)	2	1				2	
Cooper's hawk (A. cooperii)	2		2	5	7	12	
Northern goshawk (A. gentilis)						1	
Red-tailed hawk (Buteo jamaicensis)	66	124	70	97	160	28	14
Swainson's hawk (B. swainsoni)		1		55	13	1	3
Rough-legged hawk (B. lagopus)		1	3	5	1		1
Ferruginous hawk (B. regalis)	3	7	19	6	4	6	4
Harris' hawk (Parabuteo unicinctus)					4		
Zone-tailed hawk (B. albonotatus)		1			1		
American kestrel (Falco sparverius)	98	128	187	66	46	35	21
Merlin (F. columbarius)	1		5	2			1
Prairie falcon (F. mexicanus)	1	1	18	12	8		

[a] Habitat types: PP = Ponderosa pine, PJ = Pinyon-juniper, PG = Plains grassland, SDG = Semidesert grassland, CD = Chihuahuan desertscrub, R = Riparian woodland, A/U = Agricultural/Urban.

included golden eagles, bald eagles, northern harriers, rough-legged hawks, ferruginous hawks, merlins, and prairie falcons. Turkey vultures and Swainson's hawks appeared to be the only species which summered in the study area and wintered elsewhere (Table 3; Kimsey and Conley 1988).

Like Kimsey and Conley (1988), we found Chihuahuan desertscrub with power lines to be an important habitat type for golden eagles, Swainson's hawks, red-tailed hawks and northern harriers, whereas riparian habitats appear to be important for bald eagles and Cooper's hawks. Turkey vul-

tures, ferruginous hawks and American kestrels appear to be more variable in their habitat use.

Hubbard et al. (1988) found red-tailed hawks and American kestrels to be more abundant in southwestern New Mexico than elsewhere in the state. They reported an average of 2.5 red-tailed hawks/100 km and 4.1 American kestrels/100 km traveled during vehicular surveys from 1974–85. We found 13.6 red-tailed hawks/100 km and 14.1 American kestrels/100 km traveled during our surveys. We suspect these differences were largely due to differences in study design, including slower ve-

Table 3. Numbers and relative abundance (RA) of raptors observed during the AIP surveys in southwestern New Mexico, 1988–89.

SPECIES	SPRING/SUMMER		FALL/WINTER	
	NO.	RA	NO.	RA
American kestrel	440	213.5	141	68.4
Red-tailed hawk	165	80.1	394	191.2
Turkey vulture	201	97.5	2	1.0
Northern harrier	7	3.4	157	76.2
Golden eagle	20	9.7	72	34.9
Swainson's hawk	73	35.4	0	0.0
Ferruginous hawk	2	1.0	47	22.8
Prairie falcon	8	3.9	32	15.5
Cooper's hawk	7	3.4	21	10.2
Bald eagle	0	0.0	25	12.1
Rough-legged hawk	0	0.0	11	5.3
Merlin	0	0.0	9	4.4
Sharp-shinned hawk	1	0.5	4	1.9
Harris' hawk	1	0.5	3	1.4
Zone-tailed hawk	2	1.0	0	0.0
White-tailed kite	0	0.0	1	0.5
Northern goshawk	0	0.0	1	0.5

hicle speeds, increased observer numbers, and the overall focus of surveys. Hubbard et al. (1988) also found turkey vultures to be most abundant in southeastern New Mexico, followed by the southwestern portion of the state, which included our survey area. They reported observing 3.4 turkey vultures/100 km traveled in southwestern New Mexico, while we observed 4.9 turkey vultures/100 km.

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BREEDING RANGE AND CONSERVATION OF FLAMMULATED OWLS (*OTUS FLAMMEOLUS*) IN NEVADA

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Abstract.—The breeding distribution of flammulated owls (*Otus flammeolus*) in Nevada is poorly known and current range maps do not differentiate between sightings made during migration and the breeding season. We conducted owl surveys during the summers of 1992–95 and supplemented our data with published and unpublished breeding records to produce a breeding range map for flammulated owls in Nevada. In addition, we present a map of potential flammulated owl breeding localities, including mountain ranges with limber pine (*Pinus flexilis*), yellow pine (*Pinus* spp.), and fir (*Abies* spp.).

Key Words: *Otus flammeolus; owls; Strigidae; distribution; Nevada; montane; conifer.*

Rango reproductivo y conservación de *Otus flammeolus* en Nevada

Resumen.—La distribución reproductiva de *Otus flammeolus* en Nevada, es pobremente conocida y mapas de rangos actuales no hacen diferencias entre avistamientos hechos durante la migración y la estación reproductiva. Realizamos una ruta de estudio de búho durante los veranos de 1992 a 1995 y suplementamos nuestros datos con registros reproductivos publicados y no publicados para producir un mapa de rango de distribución reproductiva para *O. flammeolus* en Nevada. En suma, presentamos un mapa de potenciales localidades reproductivas, incluyendo areas montañosas con *Pinus flexilis, Pinus* spp. y *Abies* spp.

[Traducción de Ivan Lazo]

Flammulated owls (*Otus flammeolus*) are small, insectivorous, migratory raptors that have a western breeding distribution in North America extending from Guatemala north to southern British Columbia and east to the western edge of the Great Plains (A.O.U. 1983, McCallum 1994). They typically breed in mid-elevation montane habitat and are commonly associated with ponderosa pine (*Pinus ponderosa*) forests (Balda et al. 1975, Goggans 1985, Reynolds and Linkhart 1987, 1992, McCallum and Gehlbach 1988). In areas outside the Great Basin, the breeding range of flammulated owls is typically limited to mature stands of ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), or Washoe pine (*P. washoensis*) mixed with fir

(*Abies* spp. and *Pseudotsuga* spp.), quaking aspen (*Populus tremuloides*), and occasionally cottonwood (*Populus* sp.) (Marshall 1939, Johnson and Russell 1962, Phillips et al. 1964, Marcot and Hill 1980, Reynolds and Linkhart 1984, 1987, 1992, McCallum and Gehlbach 1988).

In Nevada, the pines listed above (referred to throughout as "yellow pine") are poor indicators of flammulated owl habitat. With the exception of the eastern slope of the Sierra Nevada mountain range and adjacent large mountain ranges (e.g., Carson Range), large stands of yellow pine are limited to few mountain ranges in the extreme eastern and southern portion of the state. This lack of yellow pine does not appear to limit the breeding distribution of the flammulated owl and its flexibility in breeding requirements has been documented in other portions of its range (e.g., British Columbia,

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Howie and Ritcey 1987). In Nevada mountain ranges where yellow pines are absent, flammulated owls breed in the predominant montane conifer forests which are comprised of white fir (*Abies concolor*), subalpine fir (*A. lasiocarpa*), and limber pine (*P. flexilis*) (Fig. 1).

Flammulated owls are listed as sensitive in the USFS Intermountain Region (Finch 1992), but only one of the 16 forests in this region have considered this species in a forest management plan (Verner 1994). The basic biology and status of the species in Nevada is largely unknown because of the lack of regular survey efforts aimed at identifying new populations and monitoring the ones already known to exist. The only published distribution for the species in Nevada is based on anecdotal sightings and does not differentiate between breeding and migration records (Herron et al. 1985). These data have given an erroneous impression of the range because flammulated owls are highly mobile, and sightings during migration do not necessarily indicate breeding locations. Thus, compiling known breeding locations onto a range map will provide an important and necessary contribution to our understanding of this owl in Nevada.

The focus of this study was to define a biologically relevant distribution for flammulated owls in Nevada. Knowledge of the distribution of this species is important because the limited availability of yellow pine forests has resulted in different habitat use (as has been observed in other states: Webb 1982, Howie and Ritcey 1987) demonstrating a high degree of ecological flexibility in flammulated owls. This could prove important for managing Great Basin populations.

METHODS

Surveys were conducted between 15 May–15 July from 1992–95 (Table 1). To avoid misclassifying migrating or dispersing birds as breeding individuals, only owls located between these dates were considered breeding. These dates were chosen after considering the nesting phenology reported by Reynolds and Linkhart (1987). Owls in Nevada breed at elevations similar to those in Colorado (2200–3000 m), thus extrapolating likely dates for breeding phenology seemed appropriate. Owl records and sightings occurring before 15 May and after 15 July were not used because they could have been individuals still on migration or unsuccessful breeders and fledged young exploring before return migration.

Mountain ranges with the greatest extent of suitable habitat were selected for surveys. These areas included the Schell Creek, Jarbidge, Santa Rosa, White Pine, Spring, East Humboldt, Quinn Canyon, Snake Range,

and Ruby Mountain ranges. Surveys were carried out between dusk (~2030 H) and 0100 H on nights with weather conditions that facilitated hearing singing males (e.g., low winds and no precipitation). Common poorwills (*Phalaenoptilus nuttallii*) were abundant in all areas surveyed; whenever the audibility of their singing was reduced due to weather conditions we postponed surveys until conditions improved or until a later date. Surveys were carried out either from a car if a road passed directly through appropriate habitat or on foot from ridges within large stands of conifers. At the beginning of each survey, an attempt was made to locate nesting territories by listening for singing males leaving day roosts at sunset and following them until their characteristic food delivery call was heard at nests (R. Reynolds pers. comm.). When day-roosting males could not be located at sunset, responses were elicited by imitating their territorial song vocally and with prerecorded tapes. Singing males were then followed long enough (30 min to 3 hr) to determine approximate territory boundaries. Listening to multiple males responding to each other from a ridgetop vantage point also helped us determine territory boundaries. Due to the broad area surveyed, we were not able to locate nest cavities in all potential territories. Therefore, it was assumed that singing males present from 15 May–15 July were defending territories (not necessarily breeding) and the mountain range contained potential breeding pairs. To supplement our survey data, historical records that fit our "breeding owl" definition were compiled from published literature and from museum collection records. We also recorded information concerning the type of conifer forest used (Table 1)

RESULTS AND DISCUSSION

Our study increased the number of breeding flammulated owl records in Nevada from 23 to 47 (Table 1) and provided a significant expansion of the known breeding distribution for this species in the state (Herron et al. 1985). No previous breeding records existed for the Jarbidge, Schell Creek, Santa Rosa, and White Pine Mountains (Johnson and Russell 1962, Johnson 1965, 1973, 1975, Banks and Hansen 1970, Herron et al. 1985).

Survey areas where flammulated owls were not found are not reported because an insufficient amount of time was spent to determine if they were truly absent. Nevertheless, our survey methods resulted in nesting density estimates in White Pine, Schell Creek, and Jarbidge Mountain ranges similar to those reported outside of Nevada (Reynolds and Linkhart 1987).

Our results indicate that mountain ranges supporting small patches of conifer forest <50 ha in size are suitable for flammulated owl nesting. Seligman Canyon in the White Pine Mountains was not surveyed until mid-June 1994. It contained a ~40 ha stand of white fir that contained an estimated four flammulated owl breeding territories.
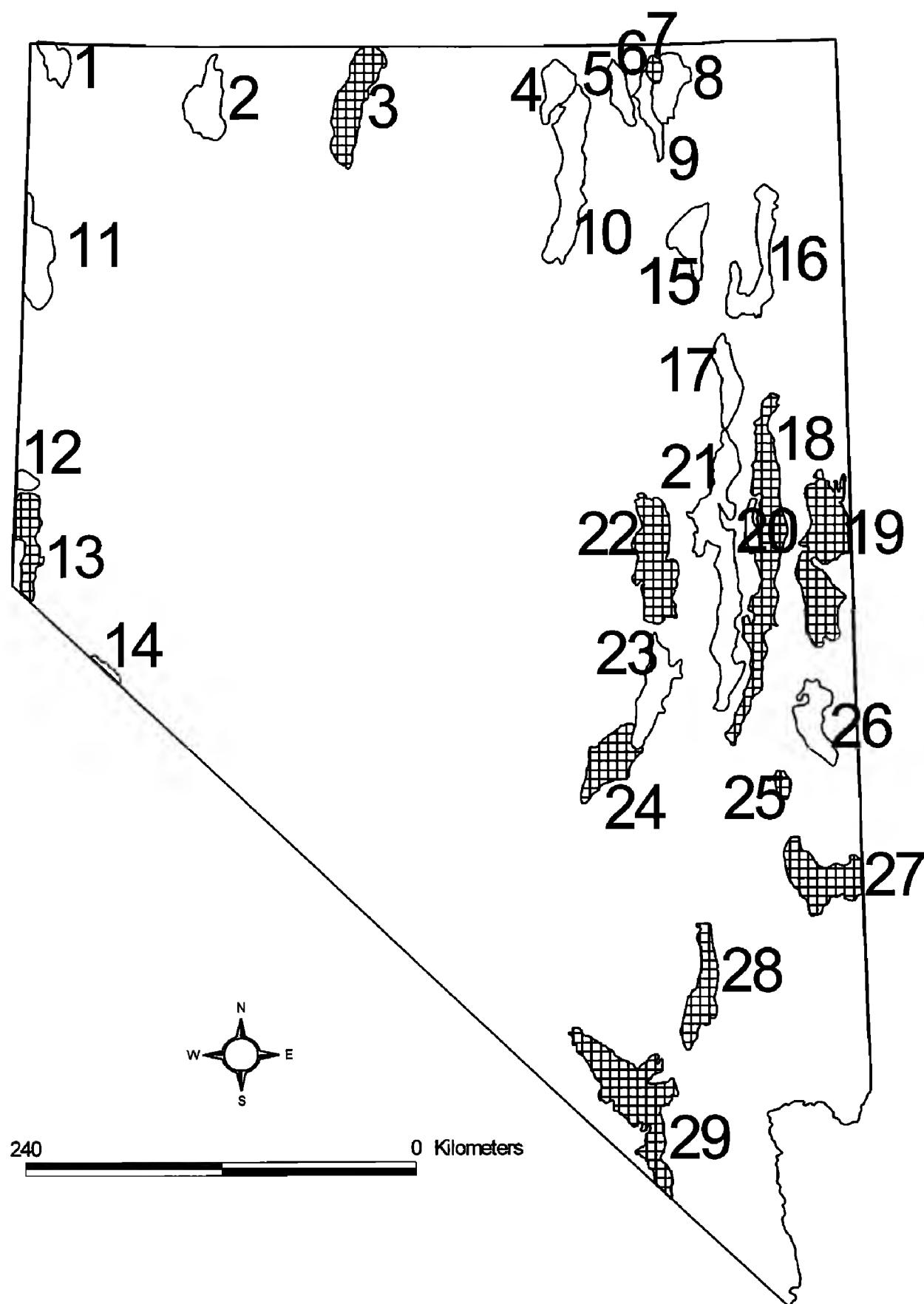
Figure 1. The known breeding distribution of flammulated owls (*Otus flammeolus*) in Nevada (dark ranges), and sites with >20 ha of potential habitat (mixed conifer forests including limber pine (*Pinus flexilis*), yellow pine (as defined in the text) (*Pinus* spp.), and white fir (*Abies concolor*) or subalpine fir (*Abies lasiocarpa*), limber pine only, and mixed aspen stands) (white ranges). Range names are: (1) Mosquito Mountains, (2) Pine Forest Range, (3) Santa Rosa Range (4) Bull Run Mountains, (5) Ichabod Range, (6) Copper Mountains, (7) Jarbidge Mountains, (8) Marys River Range, (9) Fox Creek Range, (10) Independence Mountains, (11) Madelin Mesa, (12) Peavine Mountain, (13) Carson Range, (14) Sweetwater Mountains, (15) East Humboldt Range, (16) Pequop Mountains, (17) Cherry Creek Range, (18) Schell Creek Range, (19) Snake Range, (20) Duck Creek Range, (21) Egan Range, (22) White Pine Range, (23) Grant Range, (24) Quinn Canyon Range, (25) Highland Range, (26) Wilson Creek Range, (27) Clover Mountains, (28) Sheep Range, and (29) Spring Mountains.

Table 1. Flammulated owl sightings and historical records from Nevada.

SURVEY DATES	MOUNTAIN RANGE	CANYON	NUMBER OF OWLS	DOMINANT MONTANE CONIFER[a]
1–4 July 1992	Santa Rosa	Lye Creek Campground	1[b]	Aspen
10–12 July 1992	Jarbidge	Bear Creek Meadows	8[b]	Subalpine fir, limber pine
8–14 June 1993	Spring	Lee Canyon	1[b]	Ponderosa pine
25 June 1963	Spring	Macks Canyon	1[c]	Ponderosa pine
16–19 June 1963	Spring	3 mi. N of Charleston Peak	4[c]	Ponderosa pine
17 June 1961	Spring	Clark Canyon	1[d]	Ponderosa pine
18–25 June 1993	Schell Creek	Sagehen Canyon	7[b]	White fir, limber pine
18–20 June 1972	Quinn Canyon	Scofield Canyon	1–3[e]	Ponderosa pine
29 June 1994	White Pine	Seligman Canyon	4[b]	White fir
30 June 1994	White Pine	Hoppe Springs	1[b]	White fir
6–8 June 1995	White Pine	Unnamed canyon NE of Mohawk Canyon	1[b]	White fir
3–14 June 1963	Sheep	Hidden Forest Canyon	5[c]	Ponderosa pine
26 June 1963	Clover	0.5 mi E of Ella Mountain	4[c]	Ponderosa pine
20 June 1962	Snake Range	Lexington Creek	1[f]	Ponderosa pine
5–10 June 1962	Snake Range	Snake Creek	4[f]	Ponderosa pine
22 June 1972	Highland	Water Canyon	1[e]	White fir
23 June 1972	Highland	Anderson Canyon	1[e]	White fir
17–20 May 1992	Carson Range	Thomas Creek Canyon	1[b]	Jeffrey pine

[a] Scientific names in text.
[b] This study.
[c] Johnson (1965).
[d] Banks and Hansen (1970).
[e] Johnson (1973).
[f] Johnson Museum of Vertebrate Zoology, UC Berkeley collection records.

Two of these were subsequently destroyed when nearly 75% of the fir stand was bulldozed to clear trees for construction of a large, open pit gold mine. The status of the remaining two territories adjacent to the mine pit was not known. Mohawk Canyon, Hoppe Springs, and two other unnamed canyons adjacent to Seligman Canyon were surveyed in June and July 1995 after the gold mine was constructed but only one additional singing male was found.

The frequency with which flammulated owls use small forest patches as breeding sites needs further study to adequately judge the effects of small scale habitat losses on the status of the breeding population of flammulated owls in the state. Annual survey routes should be established in all known breeding areas and in unsurveyed areas supporting patches of conifer trees. Surveys should determine the number of calling males in mountain ranges and their reproductive success to measure yr to yr population fluctuations. Multiple-yr (at least 4–5 yr in duration) studies similar to those of Reynolds and Linkhart (1987), and McCallum and Gehlbach (1988), that have focused on the nesting biology of flammulated owls, also need to be initiated to document feeding habits and habitat use of these owls when they occupy patchy habitats such as those found in the mountain ranges of Nevada. Studies of this type will provide information on the minimum patch size required by breeding flammulated owls and the extent to which they use pure stands of aspen trees in the Pine Forest Mountains, Independence Mountains, and Twin River system of the Toiyabe Mountains.

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A BANDING STUDY OF CINCINNATI AREA
GREAT HORNED OWLS

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ABSTRACT.—From 1964–92, 1570 nestling great horned owls (*Bubo virginianus*) were banded at 906 successful nests within 80 km of Cincinnati, Ohio. One nest contained four young, 40 nests three young, 581 two young, and 284 one young. Mean annual productivity was remarkably constant at 1.7 young per successful nest and 1.3 young per breeding attempt. An average of 15% of breeding pairs failed to raise young and 38% of the pairs did not attempt to nest; the number of young per occupied territory was variable but averaged 0.80 young. From 1236 nesting attempts, 533 occurred in nests built in previous years by red-tailed hawks (*Buteo jamaicensis*), 527 were in broken-off snags, and 125 were on manmade platforms. Most band recoveries occurred within the 80-km radius study area but six dead owls were found in Michigan as old as nine years of age.

KEY WORDS: *Bubo virginianus; bird banding; breeding success; brood size; nest sites; unhatched eggs; Ohio; Kentucky; Indiana.*

Estudio de marcaje de *Bubo virginianus* en el área de Cincinnati

RESUMEN.—Desde 1964 a 1992, 1570 polluelos de *Bubo virginianus* fueron marcados en 906 nidos exitosos a 80 km de Cincinnati, Ohio. Un nido tuvo cuatro juveniles, 40 nidos tres juveniles, 581 dos juveniles y 284 un juvenil. La productividad media anual fue marcadamente constante de 1.7 juveniles por nido exitoso y 1.3 juveniles por pareja reproductiva. Un promedio de 15% de parejas reproductivas falló en criar juveniles, el 38% no intentó reproducirse; el número de juveniles por territorio ocupado fue variable pero en promedio era de 0.80. De 1236 intentos reproductivos, 533 ocurrieron en nidos construidos en años previos por *Buteo jamaicensis*, 527 fueron en ramas quebradas y 125 fueron construidos sobre plataformas artificiales.

[Traducción de Ivan Lazo]

I studied nest-site selection and reproductive success of great horned owls (*Bubo virginianus*) within an 80-km radius of Cincinnati, Ohio from 1964–92. Here, I report the results of this lifelong study.

STUDY AREA AND METHODS

Most of the 20 000 km² study area was in Ohio and ranged from hilly, wooded areas to moderately settled river bottoms of the Ohio River and its tributaries, and from urban and suburban backyards, parks, cemeteries and golf courses, to fairly flat and sparsely wooded areas to the north and west of the city. The Indiana portion was hilly and heavily wooded to the south, changing to flat and sparsely settled agricultural areas to the north. The Kentucky segment was hilly throughout and ranged from heavily wooded in the north to sparsely wooded areas in the south.

The most intensive nest searching and banding occurred from 1964–77. From 1980–92, I covered only the parks of the Hamilton County Park District with a total area of 49.8 km². My experiences during the first two years of this study were described in Austing and Holt (1966).

I classified a breeding attempt by a horned owl "successful" if one or more young survived to banding age, or "failed" if incubation was begun but no young were produced. A territory was considered to be "occupied" if a pair of horned owls was present, regardless of their breeding status.

RESULTS AND DISCUSSION

I climbed into 1236 nests from 1964–92 and banded 1570 nestling great horned owls in 906 successful nests; 1193 were banded in Ohio, 324 in Indiana, and 53 in Kentucky (Table 1). More than half of the owlets were banded before they were three weeks of age. Of 1777 instances where owls occupied territories, 841 (47.3%) bred successfully, 266 failed (15%), and 670 (37.7%) made no attempt to breed (Table 2).

I found a total of 97 unhatched eggs or 5.8% of the 1667 eggs observed. Seventy-six of these were in nests that contained no young, 19 in nests with one young, and two were in nests with two young.

The Ratcliffe eggshell thickness index (Ratcliffe 1967) was determined in 1969 for 18 unhatched eggs collected in 13 nests and averaged 1.822 (Range = 1.442–2.274). This average was 8% thinner than the index of 2.01 for pre-1947 eggs from the Midwest (Anderson and Hickey 1972).

Brood size at the time of banding in 802 nests was: one young in 248 (31%) nests, two young in 515 (64%) nests, three young in 38 (5%) nests, and four young in one (0.1%) nest (Table 2). There was an attrition of 101 (6.7%) young owlets which died or disappeared prior to banding visits. The only brood of four young was encountered in 1970 when productivity reached an all-time peak. In that year, there were eight broods of three, over twice the norm, in what was called "the year of the rat." Norway rats (*Rattus norvegicus*) were almost everywhere, either killed on roads, scurrying around in cornfields and farm buildings, or even out in broad daylight. Owl nests had as many as six rats piled in them. In other years, three or four rats would have been an expected number found among prey remains in an entire nesting season.

Mean productivity per successful nest was remarkably constant throughout the study at 1.7 young per successful nest (Table 2), roughly equivalent to the success of great horned owls in Saskatchewan after a population crash of snowshoe hares (*Lepus americanus*), but far below the 2.5–2.6 young per successful nest at the peak of the hare cycle (Houston 1987, Houston and Francis 1995). The number of young per occupied territory varied considerably between years but averaged 0.80, excluding from this calculation 39 successful nests in which young were found too late to be banded. This productivity was well below the 1.47 young per nesting attempt suggested by Henny (1972) as necessary to maintain a stable population, but these calculations based on early banding recoveries may have overestimated annual adult mortality (Houston and Francis 1995). The number of young per occupied territory varied considerably by year with the number of pairs reaching a peak in 1970, the year of highest prey abundance.

Of 1236 breeding attempts, 585 pairs used nests built in previous years by other birds or mammals; 533 used nests built by red-tailed hawks (*Buteo jamaicensis*) and almost an equal number (527) made use of hollows, broken-off snags and rotted-out cavities in overmature beech (*Fagus* spp.) and maple (*Acer* spp.) trees. Artificial platforms which I constructed were used 125 times and owls nested once

Table 1. Numbers of nestling great horned owls banded near Cincinnati, Ohio from 1964–92.

YEAR	OHIO	INDIANA	KENTUCKY	TOTAL
1964	42	15		57
1965	51	14		65
1966	37	8		45
1967	51	13		64
1968	62	17	2	81
1969	84	31	1	116
1970	106	27	3	136
1971	68	17	1	86
1972	115	35	4	154
1973	87	20	9	116
1974	87	34	5	126
1975	59	13	8	80
1976	110	40	6	156
1977	77	26	11	114
1978	12	3	3	18
1979	0	0	0	0
1980	12			12
1981	25			25
1982	2			2
1983	9			9
1984	8			8
1985	10	3		13
1986	9	5		14
1987	12			12
1988	13	2		15
1989	12			12
1990	14	1		15
1991	10			10
1992	9			9
Total	1193	324	53	1570

in the hayloft of a barn (Table 3). Many pairs renested in the same territory for two or more years. Of 21 territories observed for 15 years, two were occupied by pairs of breeding great horned owls for 14 years and another two were occupied for 13 years. A total of 54 territories were used for only one year.

Owls began nesting the second week of January and continued until the first week of March. Of 903 broods which could be back-dated, 519 were initiated in January, 379 in February, and only 5 in March. Of these, 329 were initiated during the last 10 days of January and 222 were initiated in the first week of February. Early breeding pairs tended to reoccupy known sites and to raise more young than pairs that nested later. Some of the later nests may have been renesting attempts.

A total of 151 banded great horned owls were

Table 2. Brood size and productivity of great horned owl nests near Cincinnati, Ohio from 1964–92.

Year	Brood Size				Total Nests	Total Young Banded	Total Successful Nests	Total Occupied Nests
	1 yg.	2 yg.	3 yg.	4 yg.				
1964	15	18	2		35	57	1.6	1.14
1965	12	25	1		38	65	1.7	0.88
1966	8	17	1		26	45	1.7	0.63
1967	17	22	1		40	64	1.6	0.71
1968	17	29	2		48	81	1.7	0.75
1969	11	48	3		62	116	1.9	0.96
1970	18	45	8	1	72	136	1.9	1.12
1971	17	30	3		50	86	1.7	0.67
1972	23	61	3		87	154	1.8	0.99
1973	24	40	4		68	116	1.7	0.70
1974	21	48	3		72	126	1.8	0.80
1975	12	34			46	80	1.7	0.51
1976	23	59	5		87	156	1.8	0.94
1977	30	39	2		71	114	1.6	0.66
1978	6	9			12	18	1.5	
1980–92	30	60	2		90	156	1.7	
Total	284	584	40	1	906	1570	1.7	

recovered dead. About 42% (64) were reported as code "00" or found dead, another 15 were "04" or caught in traps (five of which were caught in illegal pole traps and destroyed), 14 were "14" and "45" or killed on highways, 10 were code "01" or shot, six were captured alive and released, five were captured and kept in captivity, and the status of four was uncertain. Owls were found dead throughout the year and only 16 were found dead during the fall hunting season. None of the owls reported shot were shot during the hunting season. A farmer shot both nestling owls I banded on his property because they sat on his barn roof at night and kept him awake with their food begging. Another farmer did likewise claiming that the owls were bothering his pigs.

Due to the nonmigratory nature of these great horned owls, most (141 of 151) were recovered dead within the 80-km radius of the study area. Six recoveries were of special interest; all were reported from Michigan and two of the owls were 1-yr old, two were 2-yr old, one was 6-yr old and one was 9-yr of age.

Acknowledgments

Table 3. Nests used by great horned owls near Cincinnati, Ohio from 1964–92.

	Number of Years Used									Total Nests	Total Nestlings
	1	2	3	4	5	6	7	8	9		
Red-tailed hawk[a]	263	77	24	6	1		1	1		373	533
Cavity/snag	136	63	29	18	6	5	3	2	1	263	527
Platform	22	9	11	4	6	1				53	125
E. fox squirrel[b]	17	1								18	19
American crow[c]	13									13	13
Red-shouldered hawk[d]	11									11	11
Cooper's hawk[e]	5									5	5
Green heron[f]	1									1	1
Barn loft		1								1	2

[a] *Buteo jamaicensis*; [b] *Sciurus niger*; [c] *Corvus brachyrhynchos*; [d] *Buteo lineatus*; [e] *Accipiter cooperii*; [f] *Butorides striatus*.

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EFFECTS OF PESTICIDES ON OWLS IN NORTH AMERICA

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ABSTRACT.—A literature review of the effects of pesticides on owls in North America showed that relatively few studies have been undertaken. Owls used in experiments seem as sensitive to organochlorine pesticides (OCs) as other birds of prey, but wild owls experienced few serious problems, primarily because they were exposed to lower residues in their predominately mammalian or invertebrate prey. For example, the great horned owl (*Bubo virginianus*) and the common barn-owl (*Tyto alba*) neither experienced marked changes in mortality or recruitment rates nor was there any evidence of population decreases even during the maximum period of OC pesticide use. Also, eggshell thinning was not a widespread problem. There were adverse effects on individual owls including verified records of 74 owls of six species that died from secondary or tertiary poisoning related to strychnine, organochlorines, anticholinesterases (antiChEs) and anticoagulants in 16 states within the U.S. and one province in Canada. Most of the pesticide-related deaths occurred during the 1980s, although this probably does not represent a true temporal distribution. Verified mortalities of owls probably represent a small fraction of the actual number that died from pesticides. Incidence of mortality seems biased geographically toward areas such as New York that have active ecotoxicological programs. Burrowing owl (*Speotyto cunicularia*) populations currently are decreasing throughout much of the range in the U.S. and Canada. Studies in Canada indicate that antiChE pesticides, particularly carbofuran, were responsible for the declines there.

KEY WORDS: *Owls; pesticides; mortality; secondary poisoning; reproductive effects; population decline; North America.*

Efectos de pesticidas sobre búhos en Norteamérica

RESUMEN.—Una revisión de la literatura sobre efectos de pesticidas en búhos de Norteamérica, muestra que relativamente pocos estudios han sido hechos. Búhos usados en experimentos parecen tan sensibles a pesticidas organoclorados (OC) como otras aves rapaces, en cambio búhos silvestres han sostenido pocos problemas serios, primariamente porque ellos estuvieron expuestos a residuos menores en sus presas predominantes de mamíferos e invertebrados. Por ejemplo, ni *Bubo virginianus* y tampoco *Tyto alba* experimentaron cambios marcados en la tasa de mortalidad o reclutamiento o hubo alguna evidencia de disminución poblacional durante el período de máximo uso de los pesticidas OC. El adelgazamiento de la cubierta calcárea de los huevos tampoco fue un problema importante. Hubo efectos adversos sobre individuos, que incluyeron registros verificados de 74 búhos de seis especies, que murieron por envenenamiento secundario y terciario relacionado con stricnina, organoclorados, anticolinesterasas (antiChEs) y anticoagulantes, en 16 estados de los Estados Unidos y una provincia en Canadá. La mayoría de las muertes relacionadas con pesticidas ocurrieron durante la década de 1980, aunque probablemente esto no representa una distribución temporal real. Las mortalidades verificadas de búhos probablemente representan una pequeña fracción del actual número que muere por pesticidas. La incidencia de mortalidad parece sesgada geográficamente hacia áreas tales como New York que tienen programas ecotoxicológicos activos. Actualmente las poblaciones de *Speotyto cunicularia* han decrecido en la mayor parte de su rango de distribución en los Estados Unidos y Canadá. Estudios realizados en Canadá indican que pesticidas antiChEs, particularmente carbonofurano, fue responsable de estas declinaciones.

[Traducción de Ivan Lazo]

Owls occupy upper trophic levels in various food chains. Therefore, one would expect that these birds would be as susceptible to effects of lipid-soluble organochlorine (OC) pesticides as other birds of prey. Nevertheless, there have been few intensive studies and no reviews of the effects of pesticides on owls in North America. In this review, I summarize and discuss effects of pesticides on

North American owls and briefly compare these findings with experimental studies. All residues listed are on a wet-weight basis unless otherwise stated.

EFFECTS ON REPRODUCTION

Organochlorines. Few data are available that relate effects of pesticides on reproduction of wild (free-ranging) owls. Regarding eggshell thickness, Hickey and Anderson (1968) found no shell thinning in a stationary population of great horned owls (*Bubo virginianus*) in California from 1948–50; they considered that ≥18% thinning could affect productivity immediately and could result in population declines if it occurred over several years. A more thorough study of shell thickness of great horned owl eggs, conducted in six areas in the U.S. and Canada from 1947–68, revealed no significant difference from pre-1947 norms except for 11–19% thinning in Florida (Anderson and Hickey 1972). Other studies of eggshell thickness and DDE residues in great horned owls reported 10% shell thinning associated with 5 μg/g in three eggs from New York in 1972 (Lincer and Clark 1978), no shell thinning associated with 0.7 μg/g in three eggs from Montana in 1967 (Seidensticker and Reynolds 1971) and 1.6% shell thinning associated with 3 μg/g in a study from Ohio in 1974–77 (Springer 1980).

Shell thinning of 7.4% in seven eggs of the western screech-owl (*Otus kennicottii*) collected in Oregon from 1978–81 was significantly correlated with residues of DDE in eggs; but eggshell thicknesses (N = 4–6) of the burrowing owl (*Speotyto cunicularia*), short-eared owl (*Asio flammeus*) and northern saw-whet owl (*Aegolius acadicus*) essentially were unchanged from the pre-1947 norms (Henny et al. 1984). Coincidentally, there was no evidence of adverse effects of OCs on reproductive success of five species of owls in Oregon and residues were relatively low (Henny et al. 1984). A study of great horned owls in Montana showed that low levels of DDE and other OCs had little apparent effect on the number of young fledged per nest (Seidensticker and Reynolds 1971). Klaas and Swineford (1976) found no effect of OCs on eggshell thickness or reproduction of the eastern screech-owl (*Otus asio*) in Ohio in the 1970s. A breeding study of common barn-owls (*Tyto alba*) on Chesapeake Bay, Maryland found that OC residues in eggs were associated with a slight change in eggshell thick-

ness (5.5% thinning) but little or no decrease in fledged young (Klaas et al. 1978).

Eggs of the great horned owl, snowy owl (*Nyctea scandiaca*), burrowing owl, long-eared owl (*Asio otus*) and short-eared owl collected from Canada in 1965–72 and the great gray owl (*Strix nebulosa*) collected in Minnesota in 1980–88 were analyzed for residues of OCs (Noble and Elliott 1990). Except for elevated residues of DDE (3–16 μg/g) in a few eggs of the great horned owl, short-eared owl, long-eared owl and snowy owl, residues of OCs were low; however, there were no measurements of reproductive success or eggshell thinning (Noble and Elliott 1990).

Experiments with eastern screech-owls receiving 2.8 μg/g of DDE in the diet for two breeding seasons demonstrated no significant eggshell thinning the first breeding season but 13% thinning the second year (McLane and Hall 1972). Common barn-owls given diets containing 2.8 μg/g DDE alone or 2.8 μg/g of DDE and 0.6 μg/g of dieldrin experienced eggshell thinning of 20–28%, decreases of 22–76% in young fledged per nest and mortality of several adults on dosage (Mendenhall et al. 1983). Common barn-owls receiving just 0.5 μg/g of dieldrin in the diet experienced no effects on number of young fledged, a slight decrease in eggshell thickness and deaths of several adults. Effects of DDE were similar each year even though residues in eggs averaged 12 μg/g the first year and about 40 μg/g the second year. On the 0.5 μg/g dieldrin diet, dieldrin residues in eggs of common barn-owls doubled by the second year (4–8 μg/g), but there was still no effect on the number of young fledged (Mendenhall et al. 1983).

Experimental eastern screech-owls given dicofol (Kelthone®)-contaminated diets (10 mg/kg containing either 0 or 3.4% DDT-related compounds) exhibited no effects on productivity but mean eggshell thickness was reduced 8–11% (Wiemeyer et al. 1989). In contrast, eastern screech-owls given a diet containing 0.75 mg/kg endrin produced 43% fewer fledged owlets than controls and there was no eggshell thinning (Fleming et al. 1982).

Anticholinesterases. James and Fox (1987) reported that carbofuran, but not carbaryl, was detrimental to productivity of burrowing owls in Canada. Nest success (≥1 young observed above ground) was reduced from 74% when there was no insecticide exposure within 400 m of nesting burrows to 50% and 38% when carbofuran was sprayed within 400 and 50 m, respectively. Coinci-

Table 1. Mortality of owls from organochlorine pesticides in North America.

PESTICIDE	YEAR	AREA	NUMBER OF DEATHS	SOURCE[a]
Great Horned Owl (*Bubo virginianus*)				
Chlordane	1980	Oregon	1	1
	1986–90[b]	New York and Maryland	9	2
	1982–86	New York	4	3
Dieldrin	1986–90	New York and Maryland	2	2
	1982–86	New York	1	3
	1974–81	Illinois	1	4
	1985–89	Colorado	3	5
Endrin	1981	Washington	1	6
Dieldrin + Chlordane	1982–86	New York	2	3
Several[c]	1981	New York	1	7
Several[c]	1982–86	New York	6	3
Aldrin[d]	1968 or 1970	Texas	1	8
Common Barn-Owl (*Tyto alba*)				
Chlordane	1986–90	New York and Maryland	1	2
Endrin	1981–83	Washington	4	6
Dieldrin	1982–86	New York	1	3
Eastern Screech-Owl (*Otus asio*)				
Chlordane	1986–90	New York and Maryland	3	2
Dieldrin	1982–86	New York	1	3
Several[c]	1987	Ontario	1	9
Species Not Listed				
Several[c]	1980	Ontario	1	9

[a] 1 = Blus et al. (1983); 2 = Okoniewski and Novesky (1993); 3 = Stone and Okoniewski (1988); 4 = Havera and Duzan (1986), 5 = Fordham and Reagan (1993); 6 = Blus et al. (1989); 7 = Stone and Okoniewski (1983); 8 = Flickinger and King (1972); 9 = Frank and Braun (1990).

[b] Brains of 2 additional great horned owls, 1 common barn-owl, 1 eastern screech-owl and 1 barred owl (*Strix varia*) contained near-lethal levels of chlordane components (heptachlor epoxide and oxychlordane).

[c] Deaths apparently related to combined effects of DDE, dieldrin, heptachlor epoxide and oxychlordane as well as polychlorinated biphenyls.

[d] Aldrin rapidly breaks down to dieldrin after application; therefore, animals dying as a result of aldrin use have lethal levels of dieldrin in their brains. The owl from Texas died in an area where aldrin was used.

dentally, the average maximum number of young observed per nest declined from 3.8 to 1.8 (James and Fox 1987).

PESTICIDE-RELATED MORTALITY

Organochlorines. Food chain effects (biomagnification) are important in accumulation of OC pesticides in tissues of owls. Death in the field is verified by comparing diagnostic lethal residues of OCs in tissues (preferably the brain, but the liver is sometimes used) of experimental animals exposed to one or more pesticides (Beyer et al. 1996). OCs are stored in lipids throughout the body. Residues of OCs are mobilized into the blood along with lipids during periods of food

shortage or other stress and are then transported to the brain or other compartments where they may induce mortality or serious sublethal effects (Van Velzen et al. 1972).

Deaths of 44 owls, including 32 great horned owls, 6 common barn-owls, 5 eastern screech-owls and one unidentified species, were attributed to OC pesticides (Table 1). Chlordane was involved in most of the deaths acting either as the sole toxicant ($N = 18$), combined with dieldrin ($N = 2$) or with a mixture of other OCs ($N = 9$). Nine deaths from dieldrin, five from endrin and one from aldrin were recorded from seven states and one province in Canada, but most occurred in New York. I found no records of organochlorine pesti-

cide-related deaths of owls in Mexico. After spray-
ing of DDT for Dutch elm disease in Michigan,
Bernard and Wallace (1967) reported that an east-
ern screech-owl that died in tremors had no resi-
dues of total DDT in its brain even though other
tissues contained high concentrations. I suspect
that this owl probably died from DDT poisoning,
as did many other birds in the area and that ab-
sence of residues in its brain was probably due to
an analytical error. Ferguson (1964) reported that
a barred owl (*Strix varia*) and a number of other
birds apparently died in 1960 from heptachlor af-
ter this compound was applied to a pasture in Mis-
sissippi, but tissues were not analyzed for residues.

Anticholinesterases. The relatively short-lived an-
ticholinesterase (antiChE) pesticides include or-
ganophosphorus (OP) and carbamate compounds.
These pesticides are not lipophilic and have a short
half-life in the body as well as in the environment.
The effects of these pesticides on the central ner-
vous system occur shortly after exposure, particu-
larly for carbamates. Death in the field is verified
by assaying the brain for cholinesterase (ChE) ac-
tivity; inhibition of ≥50% compared to control
birds is used as presumptive evidence that death
was related to an antiChE compound (Hill and
Fleming 1982). Analysis of the contents of the up-
per gastrointestinal tract or gizzard is used to verify
the antiChE compound involved, although resi-
dues are not always detected, particularly when
death occurs several days after exposure.

Five species of owls (18 individuals) and one un-
listed species (one individual) from 11 states were
reported killed by antiChE compounds including
the OPs phorate, famphur and fenthion; the car-
bamate carbofuran and an unknown compound
(Table 2). The record from Oregon (Henny et al.
1987) was unique because of tertiary poisoning
when a great horned owl died after consuming a
red-tailed hawk (*Buteo jamaicensis*) that ingested a
black-billed magpie (*Pica pica*) that was probably
exposed to famphur poured on the backs of cattle.
Unraveling this chain of events was only possible
because famphur is very toxic and the birds died
or were killed shortly after exposure. The famphur
study (Henny et al. 1987) was instigated because
of a report that a captive great horned owl died
after it was mistakenly fed black-billed magpies that
were apparently killed by famphur. Most records of
mortality I found were from unpublished reports
with incomplete data relating to ChE assays or res-
idue analyses.

Table 2. Mortality of owls from anticholinesterase pes-
ticides in North America.

PESTICIDE	YEAR	AREA	NUMBER OF DEATHS	SOURCE[a]
Great Horned Owl (*Bubo virginianus*)				
Phorate	1982	South Dakota	4	1, 2
Famphur	1985	Oregon	1	3
Carbofuran	1987	Virginia	1	4
	1989	Delaware	1	2, 4
	1990	Iowa	1	4
Fenthion	1993	Missouri	1	2
	1996	Washington	1	5
Unknown[b]	1986–87	Illinois	2	6
	1991	Utah	1	2
Common Barn-Owl (*Tyto alba*)				
Phorate	1989	Wisconsin	1	1
Short-eared Owl (*Asio flammeus*)				
Carbofuran	1982	Utah	1	4
Fenthion	1989	Washington	1	5
Eastern Screech-Owl (*Otus asio*)				
Unknown[b]	1986–87	Illinois	1	6
Snowy Owl (*Nyctea scandiaca*)				
Fenthion	1988	Illinois	1	5
Species Not Listed				
Carbofuran	1990	New Mexico	1	4

[a] 1 = J. Spinks, Jr., U.S. Fish and Wildlife Service (unpubl. data),
2 = Franson and Little (1996); 3 = Henny et al. (1987); 4 = L.
Lyon, U.S. Fish and Wildlife Service (unpubl. data); 5 = M
Marsh, U.S. Environmental Protection Agency (unpubl. data); 6
= Gremillion-Smith and Woolf (1993).
[b] Deaths from anticholinesterases based on cholinesterase activity
in the brain.

There were no records of owl deaths from
antiChE poisoning in Mexico or Canada. The se-
riously declining burrowing owl population in Can-
ada (Dundas 1995) has been attributed to antiChE
pesticides, particularly carbofuran (James and Fox
1987, Fox et al. 1989). Populations of burrowing
owls are also declining in the U.S., but no studies
have been conducted on pesticide involvement
(Fuller et al. 1995).

Deaths of experimental eastern screech-owls oc-
curred after they were given capsule doses of in-
dividual antiChE compounds including the OPs
EPN, fenthion and monocrotophos and the car-
bamate carbofuran. They were unusually tolerant
of the OP EPN in comparison to other species
(Wiemeyer and Sparling 1991).

Several captive eastern screech-owls died after being fed carbofuran or fenthion mixed in "meatballs" (N. Vyas pers. comm.); however, the owls were more tolerant of these antiChEs than reported by Wiemeyer and Sparling (1991).

Anticoagulants. Death from anticoagulants is more difficult to document than most other classes of compounds but hemorrhaging in tissues is usually a good indicator. Residues in tissues may be present, but they are not meaningful in a diagnostic sense (Hegdal and Colvin 1988).

Field experiments with radio-marked eastern-screech owls, common barn-owls, great horned owls and long-eared owls in Virginia showed that six eastern screech-owls and one long-eared owl apparently were killed by the rodenticide brodifacoum (on the basis of presence of residues or extensive hemorrhaging) in study areas where baits were applied (Hegdal and Colvin 1988). In experimental studies where owls were fed rodents killed by anticoagulants, two great horned owls and a northern saw-whet owl died from diphacinone and common barn-owls died from bromadiolone (one bird) and brodifacoum (five birds; Mendenhall and Pank 1980).

Cyanide. Several eastern screech-owls died after being administered gelatin capsules containing sodium cyanide (Wiemeyer et al. 1986); however, I located no records of mortality of wild owls from cyanide.

Strychnine. Strychnine is an extremely toxic, fast-acting pesticide that is used to control avian and mammalian pests. Death occurs after ingestion of treated grain or animal carcasses. Residues of strychnine in ingesta are used as an indicator of death, particularly when they equal or exceed an amount considered lethal (Redig et al. 1982).

After strychnine-treated grain was used in a rock dove (*Columba livia*) eradication program in Minnesota, three snowy owls and a great horned owl were found dead along with a number of rock doves and other birds (Table 3, Redig et al. 1982). Residues of strychnine were found in ingesta (primarily remains of rock doves) of all four owls and levels were considered lethal in two of the snowy owls and probably lethal in the other two birds (Redig et al. 1982). Secondary poisoning was not reported in other field studies (summarized by Colvin et al. 1988), and the secondary hazard from strychnine was classified as minimal.

Table 3. Mortality of owls from strychnine and anticoagulant pesticides (brodifacoum) in North America.

PESTICIDE	YEAR	AREA	NUMBER OF DEATHS	SOURCE[a]
Eastern Screech-Owl (*Otus asio*)				
Brodifacoum	1981–82	Virginia	6	1
Long-eared Owl (*Asio otus*)				
Brodifacoum	1981–82	Virginia	1	1
Snowy-Owl (*Nyctea scandiaca*)				
Strychnine	1981	Minnesota	3	2
Great Horned Owl (*Bubo virginianus*)				
Strychnine	1981	Minnesota	1	2

[a] 1 = Hegdal and Colvin (1988); 2 = Redig et al. (1982).

OTHER REALIZED OR OTHER POTENTIAL SUBLETHAL EFFECTS

Organochlorines. Several studies of OC residues in owls indicated no obvious effects. For example, Sundlof et al. (1986) analyzed brains of 30 owls (17 eastern screech-owls, 10 barred owls and three great horned owls found dead in Florida in the 1970s) for residues of OCs. Levels were below the lethal range but several contained elevated residues that may have induced other adverse effects. Generally low residues of OCs were detected in brains and other tissues of eight common barn-owls, seven great horned owls, three burrowing owls, one long-eared owl and three short-eared owls in Canada (Noble and Elliott 1990).

Anticholinesterases. Not all birds exposed to antiChEs become intoxicated and not all intoxicated birds die. For example, a radio-telemetry study of great horned owls in agricultural areas in Iowa in 1987–88 concluded that OPs had no apparent effects on survival of owls and there was slight inhibition of ChE activity in their brains (Buck et al. 1996). Common barn-owls secondarily exposed to low doses of the OP famphur in poisoned prey for 10 days experienced no overt signs of intoxication; however, there was a reduction of 34–67% in mean ChE activity in their brains (Hill and Mendenhall 1980).

Strychnine. Two captive great horned owls exhibited significant changes in behavior after they consumed mice that died after ingesting strychnine (Cheney et al. 1987); however, Wiemeyer (1989) questioned the validity of these findings be-

cause of the small sample size, no controls and re-peated use of the same owl in different tests.

Anticoagulants. Field experiments in New Jersey with radio-marked barred owls (Hegdal and Colvin 1988) and common barn-owls (Hegdal and Blaskiewicz 1984) indicated that the survival of either species and productivity of common barn-owls apparently was unaffected in areas where brodifacoum baits were applied. Two of the three common barn-owls that died after treatment exhibited signs of trauma and none had quantifiable residues of brodifacoum in their tissues.

A field experiment with eastern screech-owls and other raptors in a fruit orchard in Virginia where brodifacoum pellets were applied revealed that no quantifiable residues were detected in the mutilated carcass of one owl found dead. Two owls were euthanized several weeks after application of pellets. One owl appeared normal but the other had extensive areas of hemorrhaging and low residues of brodifacoum (Merson et al. 1984).

Zinc phosphide. Zinc phosphide is used as a rodenticide and treated grain or pellet formulatives are used. Although the baits are extremely toxic when ingested, there is little or no chance of secondary poisoning because the material breaks down rapidly. For example, captive great horned owls showed no signs of intoxication after multiple feedings on black-tailed jack-rabbits (*Lepus californicus*) that had died after ingesting zinc phosphide (Evans et al. 1970).

Mercury. Mercury was formerly used as a fungicide (seed treatment) on planted grain. Residues of mercury were recorded in eggs and livers of several species of owls in Canada in the 1960s and 1970s, but most residues were below known effect levels (Fimreite et al. 1970, Noble and Elliott 1990).

Arsenic. A pair of common barn-owls nested on a Superfund site in Texas that contained high levels of arsenic and other contaminants (S. Sheffield pers. comm.). Concentrations of arsenic were detected in tissues and prey of the barn owls. Productivity may have been reduced to some extent (10 fledged young from five nesting attempts from 1988–90) and the owls apparently ingested more invertebrate prey than usual, but effects were not linked to arsenic or other contaminants (S. Sheffield pers. comm.).

DISCUSSION

In comparison to other birds of prey, there are relatively few studies on the effects of contaminants on wild owls. There was little indication that OC pesticides exerted adverse effects on productivity or mortality of owls in North America; this was related primarily to lower residues in predominantly mammalian and invertebrate prey of owls in comparison with avian prey (Henny 1972, Noble and Elliott 1990). Sundlof et al. (1986) presented residue data for owls found dead or moribund that were arbitrarily categorized as insectivorous (eastern screech-owl) or omnivorous (barred owl and great horned owl). None of the owls had lethal levels in their brains and there were no apparent differences in residues between the two groups. Only one instance of a significant relationship between DDE residues in the egg and shell thinning was located (Henny et al. 1984). Also, only one instance of eggshell thinning of ≥18% (level associated with population declines when occurring over several years) was found (Anderson and Hickey 1972). Most studies of owls reported few effects of OCs on eggshell thinning, productivity, mortality or population trends even during the peak of OC use (Seidensticker and Reynolds 1971, Henny 1972, Klaas and Swineford 1976, Klaas et al. 1978, Lincer and Clark 1978, Springer 1980, Henny et al. 1984, Noble and Elliott 1990). Population declines of common barn-owls in the midwestern United States from the 1950s to the 1980s were thought related to habitat deterioration rather than pesticides (Colvin 1985); however, no contaminant-related studies were conducted. Coincidentally, populations of common barn-owls were stable or increasing in most of its range in the U.S. (Stewart 1980, Fuller et al. 1995).

Mortality from OCs was low with only 44 owls of three species reported killed and most of these were records from New York State in the 1980s. The temporal and geographical data seem biased toward periods and areas with active ecotoxicological programs. Most owl mortality from OCs probably occurred in the 1950s and 1960s when there was greatest use of the most toxic compounds such as DDT, heptachlor, aldrin, dieldrin and endrin. Deaths of most owls from OCs probably occurred from agricultural applications, but the three great horned owls that died from dieldrin on the Rocky Mountain Arsenal in Colorado (Fordham and Reagan 1993) apparently were exposed to high levels of OCs originating from former pesticide manufacturing plants. Further research with owls and OCs is continuing at the Rocky Mountain Arsenal (Vander Lee et al. 1995).

Experimental owls exposed to OCs seemed as sensitive as other birds of prey as they experienced mortality, reproductive problems and eggshell thinning; however, field studies revealed that owls infrequently accumulated residues sufficient to induce serious problems.

In relation to effects of antiChE compounds on owls, only 19 deaths were recorded in North America. Several of the mortalities of great horned owls from carbofuran were related to illegal deployment of laced carcasses or bait to deliberately kill wildlife (L. Lyon unpubl. data). Burrowing owls in Canada (James and Fox 1987, Fox et al. 1989) showed highly significant correlations between carbofuran spraying near nest burrows and immediate effects on reproductive success; but mortality from carbofuran was not established and there were no reports of ChE data from blood or brain samples. Other important questions regarding burrowing owls pertain to age-related sensitivity and whether their invertebrate prey base was reduced. The impacts of mercury, arsenic, zinc phosphide and cyanide on North American owls appear minimal; a few owls died from anticoagulants ($N = 7$) in field experiments and strychnine ($N = 4$).

In conclusion, it appears that owls in North America have tolerated pesticides relatively well. Only one field study indicated reproductive problems, there was little evidence of eggshell thinning, relatively few pesticide-related mortalities were reported and there was little hard evidence for pesticide-related population declines. Nevertheless, there are many relations of pesticides and owls that have received little attention. For example, limited evidence indicates that captive common barn-owls are more susceptible to anticoagulants during molting (Newton et al. 1994). More information is needed on effects of sublethal exposure on long-term survival and fecundity as well as interspecific and intraspecific differences in response to pesticides. From a contaminant standpoint, the burrowing owl is a top candidate for further study due to continued population declines in most of its range in the U.S. and Canada.

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USE OF FREE RANGING AMERICAN KESTRELS AND NEST BOXES FOR CONTAMINANT RISK ASSESSMENT SAMPLING: A FIELD APPLICATION

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ABSTRACT.—From 1989–92, American kestrels (*Falco sparverius*) were studied as part of a contaminant risk assessment in southern Iowa. Blood, fecal-urate, esophageal constriction and footwash samples were collected for chemical analyses to evaluate exposure of kestrels to an organophosphorus insecticide. To increase the number of kestrels available for sample collection, a nest box program was established. Of 56 boxes erected, 66% (37) were occupied one or more years. Mayfield nest success estimates were not statistically different between 1991, when intensive nest box monitoring and sample collection occurred (61.9%, 95% CI = 44.0–86.8%, N = 23), and 1992 when box monitoring was less intense and no biological samples were collected (56.4%, 95% CI = 29.0–108.9%, N = 15). No significant difference was detected in reproductive measurements between 1991 and 1992 (clutch size Z = −0.37, df = 40, P = 0.71; brood size Z = −1.06, df = 28, P = 0.29; number fledged/occupied box Z = 0.04, df = 39, P = 0.97; number fledged/successful box Z = −0.58, df = 26, P = 0.56). Combining 1991 and 1992 data, we found nests that failed to hatch were visited significantly more often during the pre-hatch period ($\bar{x}$ = 3.82 visits per box) than hatched nests ($\bar{x}$ = 1.91 visits per box; F = 4.06, df = 1,44, P = 0.05). Our data do not indicate that disturbance from intensive biological sampling substantially decreased American kestrel post-hatch nesting success. However, pre-hatch visits should be limited to prevent nest failure. Most nesting variables recorded in this study were similar to other studies where biological sampling disturbance did not occur.

KEY WORDS: *American kestrel; biological sampling; contaminant risk assessment;* Falco sparverius; *nest box; nest success.*

Uso de *Falco sparverius* libres y cajas anideras para muestreo de evaluación de riesgos por contaminante: una aplicación de campo

RESUMEN.—Desde 1989 a 1992, *Falco sparverius* fue estudiado como parte de mediciones de riesgo de contaminates en el sur de Iowa. Muestras de sangre, urato fecal, constricción esofageal y lavado de patas, fueron colectados para análisis químico con el fin de evaluar exposición de *F. sparverius* a un insecticidas organofosforado. Para incrementar el número de *F. sparverius* disponibles para colectar muestras, se estableció un programa de cajas anideras. De 56 cajas, el 66% (37) fueron ocupadas uno o más años. Estimaciones de éxito del nido no fueron significativamente diferentes entre 1991 (61.9%, 95% CI = 44.0–86.8%, N = 23) y 1992 (56.4%, 95% CI = 29.0–108.9%, N = 15). No se detectaron diferencias significativas en medidas reproductivas entre 1991 y 1992 (tamaño de nidada Z = −0.37, gl = 40, P = 0.71; tamaño de prole Z = −1.06, gl = 28, P = 0.29; número de volantones/caja ocupada Z = 0.04, gl = 39, P = 0.97; número de volantones/caja exitosa Z = −0.58, gl = 26, P = 0.56). Combinando los datos de 1991 y 1992, encontramos que la perturbación intensiva por muestreo biológico no causó la sustancial disminución de éxito de nidificación post-eclosión en *F. sparverius*. Sin embargo, visitas pre-eclosión podrían ser limitadas para prevenir el fracaso del nido. La mayoría de las variables de nidificación registradas en este estudio fueron similares a otros trabajos donde la perturbación por muestreo biológico no ocurre.

[Traducción de Ivan Lazo]

Because they occupy niches high on food chains and they are susceptible to bioaccumulation of environmental pollutants, raptors are often of special interest when conducting contaminant risk assessments. However, many species are difficult to study since they tend to nest at low densities and inhabit areas where access is difficult (Newton 1979). This limits the availability of samples and small sample

sizes restrict statistical analyses. Selection of the American kestrel (*Falco sparverius*) as a bioindicator species alleviates many of these difficulties. The kestrel is ideal because it is sensitive to environmental contamination, has a wide geographical distribution, feeds on a broad range of prey items, occupies relatively small home ranges, and uses nest boxes (Roest 1957, Cade 1982, Wiemeyer and Lincer 1987, Bird and Palmer 1988, Hoff 1992).

American kestrels nesting in boxes have been used to study effects of organochlorines and other contaminants on reproduction (Lincer 1975, Henny et al. 1983, Hoff 1992). However, there is little documentation of field techniques used to monitor kestrels in contaminant risk assessments and how these techniques affect reproductive success. These are important considerations when designing assessments aimed at quantifying effects of contaminant exposure on nesting parameters. The first objective of this study was to describe how an American kestrel nest box program was implemented as part of a U.S. Environmental Protection Agency mandated Tier IV, Level II Ecological Risk Assessment (Kendall 1994) designed to evaluate wildlife exposure to an organophosphorus insecticide for corn rootworms (*Dibrotica* spp.). The second objective was to evaluate kestrel reproductive performance and the impact of intensive monitoring and biological sampling on nest success associated with the risk assessment.

STUDY AREA

The study area was located in southern Lucas and northern Wayne Counties in southcentral Iowa (40°57'N, 93°18'W). American kestrels winter and breed throughout the area (Dinsmore et al. 1984). Topography ranged from nearly flat upland areas to gently rolling hills cut by intermittent streams. Most upland areas were grazed by cattle or utilized for hay, corn (*Zea* spp.) and soybean (*Glycine* spp.) production. The risk assessment was conducted on nine privately-owned farm sites, each approximately 65 ha in area and bisected by a hedgerow. Farmland adjacent to each hedgerow was in corn production during 1989 and 1991 when an organophosphorus insecticide was applied. During 1990 and 1992, farmland adjacent to hedgerows was planted to corn or soybeans, or seeded to pasture and hay fields and no insecticide was applied.

METHODS

During the fall and winter of 1988–89, four wooden nest boxes (Henderson 1984) were attached to utility poles, windmills, barns or wooden posts 2.5–6.0 m above the ground, on or within 400 m of each study site (36 boxes total). During early spring of 1990, two additional cylindrical polyvinyl chloride (PVC) nest boxes (Pasa

1989) were attached to 5 m tall utility poles centrally located on each of the nine farm sites (18 additional boxes). Two supplementary PVC boxes were placed near the periphery of one site for a total of 56 boxes. We oriented boxes to the south or southeast to increase light penetration, discourage European starling (*Sturnus vulgaris*) nesting and lessen exposure to early spring northwest weather patterns (Curley et al. 1987, Toland and Elder 1987, Wilmers 1987). At each site, distances between adjacent boxes ranged from 179–1806 m. Mean distance between boxes per site ranged from 488–914 m.

Nest boxes were visited once prior to egg laying each year to clean, repair and add wood shavings as a nest substrate. Damage to boxes or poles prior to nesting prevented some boxes from being used in various years. We visited all boxes after each breeding season to determine use. Only visits made during nesting (eggs or nestlings present) were tallied for data analysis.

We conducted risk assessment research during the late spring and early summer of 1989 (10 April–19 July) and 1991 (2 April–10 July). Biological samples were collected for analysis of pesticide exposure (Hoff 1992). In 1989, occupied nest boxes were visited up to six times (0–3 prehatch visits per box and sampled up to five times during the nesting period). In 1991, occupied boxes were visited 2–12 times pre-hatch and sampled once every 4–5 d posthatch.

In 1989 we attempted to collect blood samples from all adult (when present) and nestling kestrels found in nest boxes. In 1991 we collected blood, fecal-urate, footwash, and esophageal constriction (crop) samples (Hoff 1992, Mellott and Woods 1993, Hunt et al. 1995). Samples were collected from two or three randomly selected nestlings in each occupied box. Most nestlings in successful boxes were sampled on six different occasions before they were 25 d old. Since kestrels can fledge prior to 24 d old (Bowman and Bird 1985), crop samples were not collected from nestlings older than 20 d to prevent escape of ligatured individuals. Footwash samples were collected exclusively from adult birds pre-hatch and posthatch. Nest boxes were not visited during the nesting cycle in 1990, but were visited up to four times each (0–3 pre-hatch visits) in 1992. No biological samples were collected in 1990 or 1992.

Growth measurements including rectrix length (Balgooyen 1976), upper mandible length and tarsus length were recorded for nestlings. Rectrices were measured in 1989, 1991 and 1992 to estimate age of young. The other growth measurements were compared between sampled and nonsampled birds to assess effects of the pesticide treatment in 1991 (Hoff 1992).

In 1989, nest box visits to collect blood samples were usually less than 1 hr in length. In 1991, our sampling regime required that each box be entered twice during each sampling session. To begin a session at a box, we removed all nestlings. Esophageal constriction ligatures and fecal-urate collection diapers were attached to randomly selected young (Hoff 1992, Mellott and Woods 1993, Hunt et al. 1995). We returned nestlings to their boxes and withdrew from the immediate area to allow feeding of young by the adult birds. After a 2-hr feeding period, nestlings were again removed from their box for collection of esophageal constriction samples, fecal-urate

Table 1. American kestrel reproductive success, nest box visitation, and biological sampling data collected in southern Iowa, 1989–1992.

	1989	1990	1991	1992	$\bar{x}$ ALL YEARS
Boxes examined	36	53	56	55	50
% Boxes occupied (N)	22 (8)	21 (11)	41 (23)	42 (23)	33 (65)
Apparent nest success (N)	63 (5)	91 (10)	65 (15)	78 (18)	74 (48)
$\bar{x}$ clutch size (N)	4.7 (7)	—	4.4 (23)	4.4 (19)	4.4 (49)
$\bar{x}$ % hatching success	64 (21/33)	—	70 (71/101)	67 (56/83)	68 (148/217)
$\bar{x}$ brood size	4.2 (21/5)	—	4.4 (71/16)	4.0 (56/14)	4.2 (148/35)
$\bar{x}$ % fledging success	100 (21/21)	—	86 (61/71)	89 (50/56)	89 (132/148)
$\bar{x}$ number fledged/occupied box	2.6 (21/8)	—	2.7 (61/23)	2.8 (50/18)	2.7 (132/49)
$\bar{x}$ number fledged/successful box	4.2 (21/5)	—	4.1 (61/15)	3.8 (50/13)	4.0 (132/33)
$\bar{x}$ number of visits/occupied box	2.5 (20/8)	—	9.1 (209/23)	1.6 (36/23)	4.9 (265/54)
$\bar{x}$ number of visits/successful box	3.6 (18/5)	—	10.9 (163/15)	1.6 (29/18)	5.5 (210/38)
$\bar{x}$ number of samples/occupied box	6.0 (48/8)[a]	—	18.6 (428/23)[b]	—	15.4 (476/31)
$\bar{x}$ number of samples/successful box	9.2 (46/5)	—	26.3 (395/15)[c]	—	22.1 (441/20)

[a] Includes 48 blood samples.

[b] Includes 229 blood, 82 fecal-urate, 77 esophageal constriction, and 40 footwash samples.

[c] Includes 214 blood, 76 fecal-urate, 70 esophageal constriction and 35 footwash samples.

samples, blood samples and morphological data. Nestlings were then returned to their nest boxes. The entire sampling process required 3–3.5 hr to complete. Each session was tallied as one nest box visit.

Occupied boxes were defined as those in which at least one egg was laid. Successful boxes were those that fledged at least one young. Apparent nest success was the number of nests fledging at least one young divided by the number of observed nest initiations. Percent hatching success was defined as the number of hatched eggs per number of eggs laid. Percent fledging success represented the percent of young hatched that fledged. Boxes in 1990 were determined occupied and successful if a mat of compressed pellets lined the floor, fecal whitewash coated the interior walls and roof, and no kestrel carcasses were present. Though subjective, our experience indicated that this was a reliable method in determining nest success. With use of this method some nests initiated and lost during the egg or early brood-rearing stage may not have been detected.

We used the Mayfield Model to estimate and compare nest success between 1991 and 1992 (Mayfield 1975, Steenhof 1987, Varland and Loughin 1993, Jacobs 1995). Data from 1989 and 1990 were excluded due to small sample size.

A Wilcoxon rank-sum test was used to compare measures of reproductive success (clutch size, brood size, number fledged/occupied box and number fledged/successful box) between 1991 and 1992, using control site data only (PROC NPAR1WAY, SAS Institute Inc. 1987). Data from both years were then pooled and ranks assigned to the measures. A nonparametric analysis of variance tested for differences between treated sites and those without pesticide treatments (PROC RANK and GLM, SAS Institute Inc. 1987).

The comparison of reproductive measures between 1991 and 1992 was repeated using the Wilcoxon rank-sum test for all data (treatment and control sites combined). Additionally, the number of pre-hatch visits per nest box were assigned ranks (PROC RANK, SAS Institute Inc. 1987) and a nonparametric analysis of variance tested for differences between hatched and unhatched nests (PROC GLM, SAS Institute Inc. 1987). The same procedure compared the number of post-hatch visits of successful nest boxes between 1991 and 1992.

RESULTS AND DISCUSSION

Nest Box Use. The use of nest boxes increased substantially between 1989 and 1992 (Table 1). Of 56 boxes erected, 66% (37) were occupied one or more years. Of boxes used, 60% were occupied by kestrels two or more years, only one box was occupied all 4 yr.

A gradual increase in kestrel nest box occupancy rates can be expected over the first few years after box placement. Occupancy rate is an important consideration for risk assessments since newly established boxes provide fewer nests for sampling than boxes available more than one nesting season. Hamerstrom et al. (1973) reported an increase in box occupancy from 20% in 1968 to 30% in 1971 in central Wisconsin. Bloom and Hawks (1983) documented nest box use in California increasing steadily from 20% in 1977 to 38% in 1980, similar to the rate increases observed during our study.

Mean nest box occupancy (Table 1) in our study was comparable to other multi-year investigations (Hamerstrom et al. 1973, 26%; Bloom and Hawks 1983, 31%). Stahlecker and Griese (1979) ob-

served higher box use (73%) along a linear electrical transmission line. Varland and Loughin (1993) reported an average of 45% use on a linear highway route in Iowa.

European starlings were very common and persistently nested in boxes. This potentially reduced the number of boxes available to breeding kestrels (Cade 1982). Kestrel nests, however, were often initiated after starling nests were removed.

Nest Success. We felt it was important to determine the influence of intensive monitoring and sampling on reproductive success, as nest disturbance by observers could impact the reproductive parameters used to evaluate the effects of contaminant exposure. The comparison focused on 1991, a year of intensive monitoring and sampling, and 1992 when few visits were made to boxes. Based on apparent nest success, it might be concluded that increased monitoring and biological sampling in 1991 resulted in lower nest success (Table 1). However, apparent nest success can be inflated if nest visits are infrequent and nest failures are not detected, as was likely in 1992. The Mayfield Model of calculating nest success corrects for this bias. Mayfield nest success estimates were not statistically different between 1991 (61.9%, 95% CI = 44.0–86.8%, N = 23) and 1992 (56.4%, 95% CI = 29.0–108.9%, N = 15).

No significant difference was detected for measures of reproductive success between 1991 and 1992 on sites without pesticide treatment (clutch size Z = -0.92, df = 26, P = 0.36; brood size Z = 0.0, df = 18, P = 1.00; number fledged/occupied box Z = -0.05, df = 25, P = 0.96; and number fledged/successful box Z = 0.23, df = 17, P = 0.82). A second kestrel nest box study approximately 160 km north of our sites also found no difference between 1991 and 1992 reproductive measures (Varland and Loughin 1993). Therefore, data from both years were combined to test for an effect from pesticide treatment. No differences were detected between treated sites and those without pesticide treatments (clutch size F = 3.34, df = 1,40, P = 0.08; brood size F = 2.60, df = 1,28, P = 0.12; number fledged/occupied box F = 0.00, df = 1,39, P = 0.98; and number fledged/successful box F = 0.41, df = 1,26, P = 0.53), thus treatments were combined for further analyses. With treatments combined we detected no differences between 1991 and 1992 reproductive measures (clutch size Z = -0.37, df = 40, P = 0.71; brood size Z = -1.06, df = 28, P = 0.29; number

fledged/occupied box Z = 0.04, df = 39, P = 0.97; number fledged/successful box Z = -0.58, df = 26, P = 0.56).

Even with intensive human disturbance and biological sampling, most nesting variables recorded in this study were similar to other studies where biological sampling disturbance did not occur. Mean clutch size (Table 1) was similar to that reported by Smith et al. (1972; $\bar{x}$ = 4.7), Craig and Trost (1979; $\bar{x}$ = 4.6), Kellner and Ritchison (1988; $\bar{x}$ = 4.2), Wheeler (1992; $\bar{x}$ = 4.7) and Varland and Loughin (1993; $\bar{x}$ = 4.8). We observed mean hatching success over all years that was lower than reported by Bloom and Hawks (1983; $\bar{x}$ = 79%), but higher than reported by Smith et al. (1972; $\bar{x}$ = 67%), Kellner and Ritchison (1988; $\bar{x}$ = 65%), and observed in another Iowa study (Varland and Loughin 1993; $\bar{x}$ = 62%).

Mean percent fledging success over the 3 yr of available data was within the range reported in other studies. Other researchers observed fledging success ranging from 28–91% (Smith et al. 1972, Kellner and Ritchison 1988, Wheeler 1992, Varland and Loughin 1993). Our observed mean fledging rates also were similar to other studies (Table 1). Other researchers reported ranges from 3.1–3.6 young/occupied box and 3.7–4.0 young/successful box (Hamerstrom et al. 1973, Bloom and Hawks 1983, Wheeler 1992).

Nest Visits. Our data indicate that kestrels may be more sensitive to nest disturbance during incubation than during the nestling stage as suggested by Kellner and Ritchison (1988), and Varland and Loughin (1993). Six of 7 (86%) nest failures in 1991 and 3 of 4 (75%) in 1992 occurred before hatch. Combining 1991 and 1992 data, we found nests that failed to hatch were visited significantly more often during the pre-hatch period ($\bar{x}$ = 3.82) than hatched nests ($\bar{x}$ = 1.91; F = 4.06, df = 1,44, P = 0.05). Since nest box visits are required during incubation to estimate hatch dates, we recommend development of a method to accurately estimate hatch date based on egg weight loss (Heck and Konkel 1985). Such a method may allow observers to estimate hatch date after only one pre-hatch nest box visit, thus reducing potential abandonment.

Kestrel nests that advanced to the nestling stage were not as likely to fail as pre-hatch nests and appeared more tolerant of observer disturbance. Successful boxes were visited significantly more often during the post-hatch period in 1991 ($\bar{x}$ = 7.27)

than in 1992 ($\bar{x}$ = 1.22; F = 105.42, df = 1,31, P < 0.01), while overall Mayfield nest success was not different between years.

Nest Box Availability. When conducting an ecological risk assessment, it may be desirable to have more boxes available than will likely be used to give potential breeding pairs different options for nesting. Extra boxes may increase chances of attracting additional breeding pairs thus increasing the number of birds available for biological sampling.

Box placement is best determined in relation to study area size and shape. Varland et al. (1992) suggested spacing boxes no closer than 805 m along a linear roadside route. In contaminant studies like ours, where study site size is limited, a trade-off between providing maximum potential contaminant exposure of birds and maximum percent box occupancy and success may exist. Decreasing the distances between boxes may decrease occupancy and success rates (C.J. Henny unpubl. data), but also may increase the number of kestrels exposed to insecticide treatments and available for contaminant exposure analysis. Kestrels were most likely to be exposed to insecticide if nesting in the center of our sites. We felt it important to place more boxes in the interior of sites, even if some boxes were avoided or unsuccessful due to intraspecific territoriality caused by close box spacing. Forty percent (19 of 48) of our successful boxes were within 800 m of another successful nest, and 54% of occupied boxes within 800 m of a second occupied box were successful. The closest two successful boxes were 231 m apart. In a second pair of occupied boxes (232 m apart) only one was successful. For all sites combined, the mean distance between any two available boxes was 676 m and between any two successful boxes was 795 m. Others have recorded occupied nests 34 m (Nagy 1963), 12 m (Smith et al. 1972), 42 m (Balgooyen 1976) and 100 m (Craig and Trost 1979) apart, but did not report their success.

Our data do not indicate that disturbance from intensive biological sampling substantially decreased American kestrel post-hatch nesting success. Human disturbance does appear to negatively influence nesting success during the pre-hatch period. Pre-hatch visits should be limited to the minimum required to reliably estimate hatch dates. This tactic should reduce pre-hatch failures making more post-hatch nests available for examination and biological sampling.

American kestrel nest boxes provide a feasible method for increasing nests and birds available for intensive sampling during contaminant risk assessments and other ecological field studies. Reproductive parameters may be different between kestrel populations inhabiting nest boxes and those inhabiting natural nest cavities (Møller 1994). We assert that potential reproductive differences are not as relevant to risk assessments where treated and control sites are studied similarly.

Techniques developed recently for assessing wildlife exposure to organophosphorus compounds involve nonlethal sampling of biological fluids and waste products for analysis (Cobb and Hooper 1994). To increase sample sizes obtained from kestrel studies, a nest box route should be established preceding an impending study to encourage maximum occupancy rates. We suggest establishing a box route at least 1, preferably 2 yr prior to a field season when biological sample collection is planned.

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VARIABILITY AMONG INDIVIDUAL AMERICAN KESTRELS (*FALCO SPARVERIUS*) IN PARTS OF DAY-OLD CHICKS EATEN, PELLET SIZE, AND PELLET EGESTION FREQUENCY

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Abstract.—Seven captive, yearling male American kestrels (*Falco sparverius*) were fed intact 1-d-old chicks (*Gallus domesticus*) (high-fat diet) and eight were fed chicks with yolk sacs removed and replaced with lean turkey meat of equivalent volume (low-fat diet). The number and size of pellets (small, medium, and large) egested per day by each kestrel and the parts of the chicks not eaten were noted; parts and pellets were collected each day for 20 d. One to four pellets were egested per day by each bird. As the number of pellets egested per day increased, their size decreased. There were significant individual variations among kestrels in how often they egested each of the three sizes of pellets; however, diet had no effect on this. Egestion of one ($P = 0.0015$) or two ($P = 0.0023$) pellets per day was most common ($P < 0.05$). There were also significant differences among kestrels in how often they ate chicks entirely ($P = 0$) and how often they ate both legs ($P = 0.0324$), as well as a difference in how often they did not eat the gizzard ($P = 0.0638$) and the entire head ($P = 0.0868$).

Key Words: *Falco sparverius; pellet egestion; feeding preferences.*

Variabilidad entre individuos de *Falco sparverius* en el consumo de partes de pollo, tamaño y frecuencia de producción de egagrópilas

Resumen.—Siete machos juveniles de la especie *Falco sparverius* cautivos, comieron pollos (*Gallus domesticus*) intactos de un día de edad y ocho comieron pollos con sacos de yemas removidas y reemplazadas con carne de bajo contenido de grasa y de un volumen equivalente. Se registró el número y tamaño de egagrópilas (pequeño, mediano y grande) producidas por día por cada individuo (*F. sparverius*) y además se tomó nota de las partes de pollo no consumidas (procesadas). Se colectaron partes y egagrópilas durante 20 d. Cada ave produjo de una a cuatro egagrópilas por día. A medida que el número de egagrópilas producidas por día aumentó, su tamaño disminuyó. Hubo una variación individual significativa entre los individuos de *F. sparverius*, en cuanto a cuán a menudo ellos produjeron cada uno de los tres tamaños de egagrópilas, sin embargo, la dieta no tuvo efecto sobre esto. La producción de una ($P = 0.0015$) o dos ($P = 0.0023$) egagrópilas por día fue más común ($P < 0.05$). También hubo diferencias significativas entre individuos en cuán a menudo ellos comían pollos enteros ($P = 0$) y cuán a menudo ellos comían ambas patas ($P = 0.0324$), así como una diferencia en cuán a menudo ellos no comieron la molleja ($P = 0.0638$) y la cabeza entera ($P = 0.0868$).

[Traducción de Ivan Lazo]

The mechanism (Durham 1983) and regulation (Balgooyen 1971, Duke et al. 1976, Fuller et al. 1978) of pellet egestion are fairly well understood in falconiforms. Balgooyen (1971) and Duke et al. (1976) concluded that falconiforms egest pellets at dawn, whereas strigiforms egest when digestion of a meal is completed (Duke and Rhoades 1977, Fuller and Duke 1978, Duke et al. 1980). While the

food habits and nutritional requirements of falconiforms have been identified for most species, preferences for specific parts of prey have not been adequately described.

The objectives of the present study were to analyze individual variability among American kestrels (*Falco sparverius*) in the number and size of pellets egested per day and the parts of prey that they prefer when on high- and low-fat diets.

METHODS

Fifteen yearling, male kestrels obtained from a captive colony at the Avian Science and Conservation Centre of McGill University and maintained at the University of Minnesota on a diet of laboratory mice for 5 wk (15 September–20 October 1994) while they acclimated to individual cages (38 cm wide, 46 cm high and 46 cm deep), holding room (3.7 m wide, 5.5 m long and 2.5 m high), controlled environment (25–27°C, 45–50% relative humidity and photoperiod from 0700–2000 H), and daily feeding schedule (at 0800 H). Cages were cleaned weekly and fresh water for drinking and bathing was provided daily.

Each bird was fed either an intact 1-d-old white leghorn chick (*Gallus domesticus*)(high-fat diet) or a chick with the yolk removed and replaced with a piece of lean turkey meat of approximately equivalent volume (low-fat diet). Mean mass of the turkey meat was 10.30 ± 2.65 g (SD) while yolk weights at 21 d of incubation were less, averaging only 2.57 g ± 1.53 g (SD). Chicken egg yolks contain 50% neutral fats and 21% phospholipid (Romanoff 1960) so they have far more fat than lean meat. This amounts to an average of 1.82 g of fat per 21-d-old yolk. Lean turkey meat contains about 1.66% fat so the pieces of turkey fed to kestrels contained only about 0.073 g of fat on average. Thus, high-fat fed birds got 26 times more fat than the low-fat fed birds when both groups ate all of the food presented to them.

Kestrels were weighed upon arrival in our laboratory, 2 wk later, and then monthly for the duration of the study. Twenty min prior to each daily feeding, pellets egested during the previous 24 hr period were collected. We recorded the number collected and grouped them into small, medium, and large categories. Pellets were then dried (50°C) for 24 hr and weighed. Uneaten parts of chicks fed on previous days were also collected, identified, and recorded for each kestrel. The number of days each bird ate a particular chick part was recorded and the percentage of the days each part was eaten was calculated. A Categorical Additive Linear Model (Agresti 1990) was then performed to determine individual differences in parts consumed and the number of times particular chick parts were not eaten for low- and high-fat diet kestrels.

For each bird, the number of days that it egested 1, 2, 3, or 4 pellets was recorded. The percentage of those pellets that were small, medium, and large was calculated and the mean percentage was then determined for each kestrel on both the low- and high-fat diets. A Spearman Rank correlation was performed to determine whether a

relationship existed between the size and the number of pellets egested per day.

To determine the average size of pellets egested per day, pellets were given a ranking of 1, 2, or 3, representing small, medium, and large pellets, respectively. The average size of pellets egested by individual birds each day and average pellet size egested by each bird during the entire 20-d trial was determined. A Student's *t*-test was used to compare the average number and size of pellets egested by high- and low-fat fed birds. In order to use the Student's *t*-test, independence was assumed and the Central Limit Theorem was invoked because we calculated the mean of means. This was necessary because we did not independently identify which pellet was egested by which kestrel.

Mean percentage time required for each pellet size on both diets to be egested and the mean percentage time a particular number of pellets was egested each day was calculated for the 20-d collection period. Individual percentages of egestion for each bird and mean percentages were compared using a Categorical Additive Linear Model.

To measure the association between number of pellets egested by kestrels and the parts of the 1-d-old chicks they ate, a Fisher's Exact Test (2-Tail) was performed. All birds were considered together. Unless otherwise noted, all results of all analyses were considered to be significantly different when $P < 0.05$.

RESULTS AND DISCUSSION

Mean body mass of the high-fat fed kestrels was 98.08 ± 3.338 g (SD) at the beginning of the study and 109.62 ± 3.29 g at the end. For the low-fat fed individuals, initial mean body mass was 102.19 ± 2.67 g and final mass averaged 107.21 ± 2.61 g. A repeated measures ANOVA indicated that there was no difference in the effect of diet averaged over all days ($P = 0.7917$) or for each day ($P < 0.3611$) on body mass gain. In comparison with the first day of our experiment, all birds gained mass on each successive day ($P < 0.0005$) but diet had no effect on this ($P < 0.0787$).

Between bird comparisons showed there were significant differences in the percentage of time whole chicks (AW) were eaten ($P = 0$) and when both legs (DeL-2) were not eaten ($P = 0.0324$). There were also differences between birds in not eating the gizzard (DeG) ($P = 0.0638$) and not eating the head (DeH)($P = 0.0868$)(Tables 1 and 2).

A Spearman Rank correlation analysis indicated no correlation between body mass and the percentage of time kestrels ate prey entirely ($P = 0.09237$). This suggested that individual differences in metabolic rates among kestrels caused some to require less daily food intake than others. Individual preferences may have also been related

Table 1.   Percentage of time high-fat fed kestrels ate various parts of 1-d-old chicks over a 20-d collection period.

BIRD	AW[a]	DE-1/2	DEH	DEH-1/2	DEB	DEG	DEL-1	DEL-2	DEY
1	70	0	0	0	5	0	15	15	0
2	70	0	0	0	5	15	15	5	5
3	30	0	5	0	5	0	35	15	15
4	15	0	20	0	10	35	35	15	0
5	25	0	0	0	15	40	20	30	5
6	25	0	5	5	10	30	35	25	0
7	25	10	5	0	10	25	15	25	5

[a] AW—ate whole chick; De-1/2—did not eat half of the chick; DeH—did not eat chick head; DeH-1/2—did not eat half of the chick head; DeB—did not eat beak; DeG—did not eat gizzard; DeL-1—did not eat one leg; DeL-2—did not eat both legs; DeY—did not eat yolk.

to differences in metabolic requirements. Eating gizzards ($P = 0.0638$), heads ($P = 0.0868$) or legs ($P = 0.0324$), for instance, probably required more time and effort to reduce these organs to pieces small enough to be swallowed increasing the metabolic needs of kestrels compelled to eat these parts.

To our knowledge, it has not been previously reported that small raptors selectively consume specific parts of their prey. It is known that kestrels select certain kinds of prey (Bryan 1984) or select prey on the basis of size (Marti and Hogue 1979, Overskaug et al. 1995) and activity level (Sarno and Gubanich 1995). Differences in the parts of 1-d-old chicks eaten were not expected because the kestrels used in this study were from a captive-bred colony, all derived over 20 generations from a common genetic stock consisting of 10 pr captured in the Montreal area. Additionally, they were maintained, fed and managed similarly in captivity.

Comparison of low- and high-fat diets revealed that there was no effect of diet on what parts of

the chick the birds did or did not eat ($P > 0.2257$) (Table 3).

A negative correlation between pellet size and the number of pellets egested per day was found for large pellets in both high- ($R = -0.6474$, $P = 0.0008$) and low-fat fed kestrels ($R = -0.7546$, $P = 0.0001$), whereas a positive correlation existed between number of pellets egested and small pellets for both high- ($R = 0.7565$, $P = 0.0001$) and low-fat fed birds ($R = 0.6632$, $P = 0.0003$). The same correlation existed for small ($R = 0.7045$, $P = 0.0001$) and large ($R = -0.6934$, $P = 0.0001$) pellets when all birds were considered together. Thus, as the number of pellets egested per day increased, the percentage of those pellets that were small increased.

Pellets classified as small, medium, or large were weighed and the mean weights for each of the three size groups were determined. On average the small, medium, and large pellets weighed 0.1280 ± 0.0094 ($N = 78$), 0.2541 ± 0.0062 ($N = 178$), and 0.4018 ± 0.0066 ($N = 157$) g, respectively.

Table 2.   Percentage of time low-fat fed kestrels ate various parts of 1-d-old chicks over a 20-d collection period.

BIRD	AW[a]	DE-1/2	DEH	DEH-1/2	DEB	DEG	DEL-1	DEL-2	DEM	DEM-1/2
8	20	0	0	0	0	20	0	5	70	0
9	10	5	0	0	5	5	20	40	75	5
10	95	0	0	0	0	0	0	0	5	0
11	10	0	5	0	5	0	10	0	85	0
12	10	0	5	0	5	25	30	10	60	5
13	5	0	30	0	10	0	20	0	80	0
14	10	0	5	0	10	15	25	35	70	0
15	0	0	20	0	10	0	30	30	85	0

[a] AW—ate whole chick; De-1/2—did not eat half of the chick; DeH—did not eat chick head; DeH-1/2—did not eat half of chick head; DeB—did not eat beak; DeG—did not eat gizzard; DeL-1—did not eat one leg; DeL-2—did not eat both legs; DeY—did not eat yolk; DeM—did not eat turkey meat; DeM-1/2—did not eat half of the turkey meat.

Table 3. Mean percentage of time (±SD) kestrels on high- and low-fat diets ate various parts of 1-d-old chicks over a 20-d period.

PARTS OF CHICK EATEN	HIGH FAT $(N = 7)$	LOW FAT $(N = 8)$
AW[a]	37.1 ± 8.7	20.0 ± 10.9
De-1/2	1.4 ± 1.4	0.6 ± 0.6
DeH	5.0 ± 2.7	8.1 ± 3.9
DeH-1/2	0.7 ± 0.7	0 ± 0
DeB	8.6 ± 1.4	5.6 ± 1.5
DeG	20.7 ± 6.1	8.1 ± 3.7
DeL-1	24.3 ± 3.8	16.9 ± 4.3
DeL-2	18.6 ± 3.2	15.0 ± 6.1

[a] AW—ate whole chick; De-1/2—did not eat half of the chick; DeH—did not eat chick head; DeH-1/2—did not eat half of the chick head; DeB—did not eat beak; DeG—did not eat gizzard; DeL-1—did not eat one leg; DeL-2—did not eat both legs; DeY—did not eat yolk.

It is interesting that the kestrels in this study often egested more than one pellet per day when earlier studies (Balgooyen 1971, Duke et al. 1976) indicated that falconiforms egest only one pellet at dawn. This could have been related to the fact that birds in earlier studies were given a meal, then uneaten remains were collected after 1 hr. In our study, food was left for 24 hr so birds had the opportunity to eat several meals and egest several pellets over the day. Digestion of several smaller meals may be more thorough than digestion of one large meal. It is likely that free ranging raptors egest many times daily and, in so doing, their stomachs are not kept partially filled with indigestible materials during the day. This would be especially detrimental to small raptors with high metabolic rates and high demands for daily food intake. Clearly, more studies of pellet egestion should be undertaken using variable feeding times and meal sizes to better simulate natural conditions.

Although there was variability in the number of pellets egested per day among the birds (Table 4), there was not a significant difference in the number of pellets egested per day for the two diets (P = 0.6994). High-fat fed birds egested an average of 1.62 ± 0.39 pellets per day, and low-fat fed birds egested an average of 1.55 ± 0.31 pellets per day. There was an effect of diet on the size of the pellets, however, with birds eating the low-fat diet producing significantly larger pellets (P = 0.0461). This difference was probably related to the lipid content of the diet. Lipid in the duodenum is

Table 4. Mean number and size (small = 1, medium = 2 and large = 3) of pellets (±SD) egested per day by kestrels over a 20-d period.

BIRD	MEAN NUMBER OF PELLETS EGESTED PER DAY	MEAN SIZE OF PELLETS EGESTED PER DAY
1	0.90 ± 0.79	1.40 ± 1.18
2	1.80 ± 0.89	1.77 ± 0.81
3	1.25 ± 0.85	1.88 ± 1.09
4	2.00 ± 1.08	1.73 ± 0.66
5	1.80 ± 0.89	2.05 ± 0.83
6	1.80 ± 1.01	1.69 ± 0.71
7	1.80 ± 0.83	2.09 ± 0.48
8	1.85 ± 0.67	2.07 ± 0.63
9	1.75 ± 1.07	1.95 ± 0.88
10	1.20 ± 0.41	2.60 ± 0.50
11	1.00 ± 0.46	2.35 ± 0.99
12	1.45 ± 1.05	1.64 ± 0.89
13	1.80 ± 0.77	2.04 ± 0.63
14	1.70 ± 0.86	2.20 ± 0.79
15	1.65 ± 0.75	1.98 ± 0.66

known to slow gastric emptying (Duke and Evanson 1972) and the enterogastric reflex in turkeys and all mammals so far examined (Argenzio 1993). Slowing of this reflex in a raptor on a high-fat diet would increase the time food remains in the stomach increasing gastric digestion and reducing the size of pellets. Since this was the only effect of diet observed, fat content did not appear to be an important factor in overall food intake or digestion in kestrels.

Between bird comparisons showed individual differences in the mean percentage time required for the egestion of small (P = 0.0417), medium (P = 0.0020), and large (P = 0.0418) pellets (Table 5). There was no discernible effect of diet on the percentages for small (P = 0.3145), medium (P = 0.5195), and large (P = 0.7516) pellets. High-fat fed birds egested small pellets 35.7 ± 5.9, medium pellets 56.4 ± 6.0, and large pellets 35.7 ± 5.2% of the time. Whereas low-fat fed birds egested small, medium, and large pellets 26.3 ± 4.9, 54.4 ± 7.1, and 44.4 ± 5.7% of the time, respectively. The total of these percentages is greater than 100% because birds egested more than one pellet a day.

Comparisons of the days kestrels egested 1, 2, 3, or 4 pellets showed significant individual differences in percentages for egesting one (P = 0.0015) or two (P = 0.0023) pellets per day (Table 6).

Table 5. Percentage of time kestrels egested small, medium, and large pellets over the 20-day collection period.

BIRD	SMALL[a]	MEDIUM[b]	LARGE[c]
1	15	40	20
2	40	70	40
3	35	30	50
4	50	70	20
5	15	70	45
6	55	60	25
7	40	55	50
8	35	65	40
9	45	40	35
10	10	30	70
11	05	25	60
12	35	60	20
13	20	80	40
14	25	65	55
15	35	70	35

[a] $P = 0.0417$; [b] $P = 0.0020$; [c] $P = 0.0418$.

NOTE: The total of the percentage for each bird is greater than 100% because each bird may have egested more than one pellet per day.

Comparison of mean percentages showed that diet had no effect on the mean percentage of time high-fat versus low-fat fed kestrels egested zero (11.4 ± 26.9% vs. 6.0 ± 1.9%, $P = 0.3554$), one (35.0 ± 4.0% vs. 46.9 ± 3.9%, $P = 0.3297$), two (36.4 ± 4.1% vs. 35.0 ± 3.8%, $P = 0.2005$), three

Table 6. Percentage of time kestrels egested 0, 1, 2, 3, and 4 pellets per day over a 20-d collection period.

BIRD	0 PELLETS[a]	1 PELLET[b]	2 PELLETS[c]	3 PELLETS[d]	4 PELLETS[e]
1	35	40	25	0	0
2	10	15	65	5	5
3	15	55	20	10	0
4	5	30	35	20	10
5	10	20	50	20	0
6	5	40	30	20	5
7	0	45	30	25	0
8	0	30	55	15	0
9	5	50	15	25	5
10	0	80	20	0	0
11	10	80	10	0	0
12	15	45	25	10	5
13	5	25	55	15	0
14	10	30	50	5	5
15	5	35	50	10	0

[a] $P = 0.3198$; [b] $P = 0.0015$; [c] $P = 0.0023$; [d] $P = 0.4576$; [e] $P = 0.9985$.

(14.3 ± 3.0% vs. 10.0 ± 2.4%, $P = 0.1081$), and four pellets per day (2.9 ± 1.4% vs. 1.9 ± 0.1%, $P = 0.6726$). Zero or four pellets per day were least frequently observed, while one or two egested per day was the most frequent egestion pattern.

A significant association existed between the number of pellets egested and parts of the chick eaten when they did not eat the gizzard (DeG) ($P = 0.014$) and ate only half of the head (DeH-1/2) ($P = 0.023$). It is not clear how not eating the gizzard might affect the number of pellets egested, since the gizzard would presumably be completely digested with no parts incorporated into a pellet. On the other hand, not eating one half of the head could affect the number of pellets egested since parts of the beak and skull may be incorporated into a pellet as would any feathers on the head.

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FACTORS INFLUENCING THE SIZE OF SOME INTERNAL ORGANS IN RAPTORS

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ABSTRACT.—The size of the small intestine, stomach, kidney, liver and heart were compared among raptor species and considered in relation to hunting strategy and body size. Species relying on rapid acceleration and maneuverability to capture prey in flight, such as sparrowhawk (*Accipiter nisus*), goshawk (*A. gentilis*), and peregrine (*Falco peregrinus*), had the smallest digestive tracts for their size. Species depending more on soaring flight which do not need fast acceleration to capture prey, such as common buzzard (*Buteo buteo*), red kite (*Milvus milvus*), and European kestrel (*Falco tinnunculus*), had heavy digestive organs. In the Strigiformes, the same relationship was found, and species which hunt by active flight, such as barn owl (*Tyto alba*), and long-eared owl (*Asio otus*), had significantly lighter digestive tracts than the tawny owl (*Strix aluco*), a species which mainly hunts from a perch dropping onto its prey from above. Body condition was positively correlated with organ weights, including the heart, but to a lesser extent with linear measures of size such as intestine length.

KEY WORDS: *internal organs; predatory birds; condition.*

Factores que influencian el tamaño de algunos órganos internos en rapaces

RESUMEN.—El tamaño del intestino delgado, estómago, riñones, hígado y corazón, fue comparado entre especies de rapaces que difieren en estrategia de caza y tamaño corporal. Especies basadas en rápida aceleración y maniobrabilidad para capturar presas en vuelo, tales como *Accipiter nisus*, *A. gentilis* y *Falco peregrinus* tenían el tracto digestivo más pequeño para su tamaño corporal. Especies que dependen más bien de un vuelo de planeo y que no necesitan de una rápida aceleración, tales como *Buteo buteo*, *Milvus milvus* y *Falco tinnunculus*, tenían órganos digestivos más pesados. En Strigiformes se encontró la misma relación, especies que cazan por vuelo activo, tales como *Tyto alba*, *Asio otus*, tenían un tracto digestivo significativamente más liviano que *Atrix aluco*, una especie que caza esperando a la presa desde una percha. La condición corporal estuvo correlacionada positivamente con el peso de los órganos, incluyendo el corazón.

[Traducción de Ivan Lazo]

We previously reported that birds of prey show considerable variation in the length of their small intestines (Barton and Houston 1994) and suggested that these differences could be due to adaptations for different styles of predation. We hypothesized that raptors which capture prey by pouncing on it from above would have the longest gut lengths for efficient digestion while species which need to accelerate rapidly to capture active prey, such as predators taking small prey in flight, would have very light organ systems to enable them to accelerate more rapidly. Reduction in the length of the small intestine probably results in less efficient absorption of food but this could still be selected for if this disadvantage were more than compensated for by a higher rate of prey capture. We were able to demonstrate that there was an as-

sociation between the length of the small intestine and the predatory strategy shown by a species, and that after correcting for differences in body size, those species that specialized in the capture of small birds in flight had small intestinal lengths up to 50% shorter than species with a less active predatory style. The small intestine is responsible for nutrient absorption and is therefore the organ most likely to effect absorption efficiency. We have shown that species with short small intestines digest their food less efficiently, and as a consequence select only prey items of high energy content (Barton and Houston 1993a, 1993b).

This paper considers whether there may be associations between predatory strategy and the weight of other organ systems. We compared the mass of the gizzard, proventriculus, small intestine,

Table 1. Mean wet weights (±SD) of internal organs of various raptors expressed as a percentage of total body weight. Means are based on a combination of the sizes of internal organs of both sexes and sample sizes are given in parentheses.

Species	Liver	Heart	Kidney	Stomach	Small Intestine	Body Mass
Kestrel	3.24 ± 0.46 (14)	1.13 ± 0.14 (12)	1.14 ± 0.22 (10)	2.62 ± 0.34 (12)	0.75 ± 0.42 (18)	180
Merlin	3.24 ± 0.84 (3)	2.20 ± 0.31 (3)	1.10 (1)	1.56 ± 0.32 (3)	0.56 (1)	190
Sparrowhawk	2.63 ± 0.53 (86)	1.12 ± 0.14 (75)	0.81 ± 0.12 (59)	0.95 ± 0.13 (38)	0.63 ± 0.28 (22)	220
Peregrine	2.76 ± 0.43 (3)	1.81 ± 0.05 (3)	0.86 ± 0.2 (3)	1.24 (1)	0.53 ± 0.05 (3)	760
Buzzard	2.15 ± 0.47 (5)	0.86 ± 0.15 (31)	0.92 ± 0.05 (3)	1.48 ± 0.41 (4)	0.99 ± 2.62 (7)	850
Red Kite	—	1.13 ± 0.26 (7)	—	—	—	1040
Goshawk	1.65 ± 0.36 (50)	0.86 ± 0.09 (44)	—	—	0.46 (1)	1110
Long-eared owl	2.10 (2)	0.98 ± 0.28 (6)	0.84 (2)	1.93 (1)	0.75 (2)	270
Barn owl	2.83 (40)	0.87 (38)	0.78 (36)	1.94 (12)	0.42 (2)	310
Short-eared owl	3.17 (2)	1.22 (2)	0.98 (1)	2.48 (1)	1.64 (1)	350
Tawny owl	2.55 ± 0.19 (3)	0.71 ± 0.10 (3)	—	1.91 (2)	1.26 ± 0.38 (3)	460

liver, and kidney between eight species of Falconiformes and four Strigiformes. We also examined heart weight in these species to see if this is heavier in species with an energetic form of prey capture. Finally, we considered the correlation between body condition and the size of these organs.

METHODS

Most of the birds used in this study had been found dead and sent to the Institute of Terrestrial Ecology as a part of their program to monitor pesticide residues. In addition, a sample of goshawks was examined which had been shot under license for game preservation and imported under license (CITES 038371A). Birds were stored frozen at −20°C for up to 6 wk. It is known that freezing has little effect on gut morphology, but prolonged periods between death and freezing can lead to

significant loss in tissue weight (Barton and Houston 1992); we therefore discarded any birds which had obviously lain for some time before being frozen.

In order to test our hypothesis, we first needed to categorize the predatory style of each raptor species. For the Falconiformes we did this based on literature review of the proportion of avian prey in each species diet. Species taking more than 75% avian prey were categorized as attackers and included peregrine falcons (*Falco peregrinus*), sparrowhawks (*Accipiter nisus*), and goshawks (*A. gentilis*), while species taking predominantly small mammals and carrion were categorized as searchers and included buzzard (*Buteo buteo*), red kite (*Milvus milvus*), and kestrel (*Falco tinnunculus*) (Brown 1978). Attackers were species which capture prey by high-speed aerial chase, requiring great acceleration and agility with an average hunting success of 13% (Temeles 1985). Searchers, however, were species capturing mammalian prey mainly

Table 2. Correlation between organ size (g) and index of body condition of various species of raptors. Sample sizes given in parentheses.

Species	Sex	Gizzard	Heart
Sparrowhawk	M	$r = 0.71$, $P = 0.0018$ (16)	$r = 0.89$, $P = 0.02$ (6)
	F	$r = 0.53$, $P = 0.0018$ (32)	$r = 0.63$, $P = 0.02$ (13)
Peregrine	M	$r = 0.96$, $P = 0.03$ (4)	$r = 0.96$, $P = 0.01$ (5)
Kestrel	M	$r = 0.55$, $P = 0.09$ (10)	—
	F	—	$r = 0.80$, $P = 0.03$ (7)
Buzzard	M	$r = 0.93$, $P = 0.0001$ (10)	$r = 0.87$, $P = 0.0001$ (16)
	F	—	$r = 0.77$, $P = 0.0003$ (17)
Red Kite	M	$r = 0.69$, $P = 0.31$ (4)	$r = 0.95$, $P = 0.004$ (6)
Goshawk	M	$r = 0.33$, $P = 0.12$ (23)	$r = 0.58$, $P = 0.002$ (25)
	F	$r = 0.44$, $P = 0.07$ (18)	$r = 0.79$, $P = 0.0001$ (19)
Barn Owl		$r = 0.34$, $P = 0.19$ (16)	$r = 0.78$, $P = 0.02$ (8)
Tawny Owl		—	$r = 0.72$, $P = 0.28$ (4)

by dropping on it from above and not depending so heavily on high-speed powered flight, with higher rates of prey capture (Temeles 1985). For the owl species examined, the main difference in hunting strategy between species was that barn owls (*Tyto alba*) and long-eared owls (*Asio otus*) have an active flight mode with prey mainly located while in flight, while tawny owls (*Strix aluco*) are more passive predators, locating prey from perch sites (Cramp and Simmons 1980).

There was some variation in the condition of the birds available for this study. We used dry weights to record organ mass because we did not know the extent to which carcasses had become dehydrated after death. Wet weights were used only from birds known to have died accidentally and whose carcasses were collected shortly after death.

The proventriculus, gizzard, small intestine, liver, kidney, and heart were dissected from 583 carcasses. Stomachs were separated into the proventriculus, whose function is the production and release of gastric secretions, and the gizzard, which provides mechanical digestion and preliminary proteolysis (Duke 1986). The length and width of the proventriculus were measured when laid flat to estimate internal surface area. All other organs were cleaned of mesentery and fat bodies; the heart had the chambers opened and any blood clots removed. All tissues were then oven dried at 70°C to constant weight. The combined weight of proventriculus and gizzard is here referred to as stomach, and the combined mass of proventriculus, gizzard, and small intestine as gut. Falconiformes were analyzed separately by sex, because of their sexual dimorphism, and sufficient data were available to analyze male and female sparrowhawks, peregrine falcons, kestrels, common buzzards, red kites, and goshawks separately. We used a skeletal body size variable to correct for differences in body size between species (Barton and Houston 1994).

We used Principal Components Analysis to identify which of the six body measures were best predictors of body size, and identified the length of the sternum keel (from base of the sternum to anterior edge of the keel)

Table 2. Extended.

SMALL INTESTINE LENGTH	SMALL INTESTINE DRY WEIGHT
$r = 0.51, P = 0.009$ (25)	$r = 0.45, P = 0.06$ (18)
$r = 0.06, P = 0.72$ (39)	$r = 0.30, P = 0.07$ (36)
$r = 0.14, P = 0.79$ (6)	$r = 0.95, P = 0.01$ (5)
$r = 0.60, P = 0.12$ (8)	$r = 0.89, P = 0.001$ (9)
$r = 0.15, P = 0.63$ (13)	$r = 0.79, P = 0.0005$ (15)
$r = 0.60, P = 0.01$ (17)	$r = 0.69, P = 0.0017$ (18)
$r = 0.09, P = 0.70$ (22)	$r = 0.34, P = 0.12$ (22)
$r = 0.63, P = 0.18$ (6)	$r = 0.99, P = 0.0001$ (6)
$r = 0.09, P = 0.65$ (25)	$r = 0.04, P = 0.83$ (25)
$r = 0.35, P = 0.13$ (20)	$r = 0.69, P = 0.001$ (19)
$r = 0.28, P = 0.17$ (24)	$r = 0.37, P = 0.14$ (17)
$r = 0.99, P = 0.004$ (4)	$r = 0.95, P = 0.05$ (4)

and sternum diagonal length (from base of sternum to distal point of coracoid) as the best predictors. We used the product of these two measures as our body size factor and used this factor as the covariate in ANCOVA analysis to correct for body size differences. We log-transformed data on both axes. The Bonferroni method was used for pairwise comparison of adjusted treatment means (Day and Quinn 1989).

Since our study dealt with evolutionary adaptation of digestive organ size with relation to hunting strategy, we considered including a phylogenetic component in our analysis. However, since the species sample was small and we had species with contrasting hunting strategies in the same genus, we decided there would be no advantage to adding a phylogenetic component.

To consider the contribution that each organ makes to total body mass, we used a smaller sample of fresh carcasses to obtain wet weights of liver, kidney, proventriculus, gizzard, small intestine, and heart. The weight of each organ was calculated as a percentage of total body mass.

We dissected the pectoralis muscle from each carcass After weighing, it was dried at 70°C to constant weight. Larger species had 10 g samples of muscle tissue dried, from which total muscle dry weight was estimated from the wet weight of the sample and total muscle. Subsamples were shown to be representative of the whole muscle. A condition index which accounted for body size differences was then calculated by regressing the dry weight of the two pectoral muscles against the skeletal body size measure and saving the residuals. The variables being examined were standardized in the same way, again saving the residuals. Correlations between the two sets of residuals were then examined.

RESULTS

Male and female sparrowhawks and goshawks had the lightest gizzards and stomachs for birds of their size, while red kites and common buzzards had the heaviest. Sparrowhawks had the lightest small intestines and common buzzards and red kites the heaviest. When total mass of the gut was considered, the guts of the goshawk, sparrowhawk, and peregrine were the lightest for their body size and those of the kestrel and common buzzard the heaviest. All comparisons were significant ($P < 0.05$) with no significant heterogeneity in regression slopes. In considering heart weight, there were significant differences among the species examined, but these were not consistent. Among males, kestrels had the largest heart relative to body mass but, in females, goshawks and sparrowhawks were heavier.

Among owls, the tawny owl had a significantly heavier proventriculus, small intestine, and total digestive tract than expected for a bird of this size. There were no significant differences in heart weight between owls.

We were not able to obtain dry weights for liver and kidney tissue but determined their wet weights as a percentage of total body weight (Table 1). This was a less satisfactory method of indicating relative organ size because birds differed in their fat content, gut content, and overall muscle condition making body weight a poor predictor of actual body size (Barton and Houston 1994). To minimize this problem, we only included data from birds which were freshly killed from accidental causes and which seemed to be in good condition. Sample sizes were small but there is no indication that liver, kidney, or heart mass was associated with predatory strategy. Liver and kidney made up approximately the same proportion of body mass across all species. The largest relative heart size was found in the peregrine and merlin (*Falco columbarius*) both of which have high power output requirements. However, the goshawk and buzzard, two species with directly contrasting hunting strategies, had the same relative heart size.

Stomach size was variable. The kestrel had a very large stomach for a bird of its size. Compared to the sparrowhawk, the kestrel had a stomach three times larger. The relative size of the kestrel gut more closely resembled that of the Strigiformes suggesting it might be a dietary adaptation for species feeding largely on small mammals.

We used weight of the pectoral muscle as an index of body condition because this varies considerably and is the largest muscle in the body of a bird. Individuals which we categorized subjectively as having died of starvation had on average only 54% of lean dry pectoral muscle weight compared to that found in individuals which had been killed by collisions. For all species there was a significant positive correlation between condition and the weight of the small intestine (Table 2). The length of the small intestine was also positively correlated with condition in male sparrowhawks, male buzzards and tawny owls. Gizzard weight was also found to be significantly correlated with body condition for sparrowhawks, male peregrines, and male common buzzards. Heart weight was highly correlated with condition in every species except the tawny owl.

DISCUSSION

In an earlier analysis we showed that the length of the small intestine in raptors varied between species and seemed to be strongly associated with the predatory strategy. However, length might not al-

ways be the best measure of gut tissue because the alimentary tract can stretch, so that differences in length may not necessarily reflect a corresponding difference in tissue mass. Here we have shown that small intestine tissue weight also varies between species, and that those species with an attacking mode of predation have significantly less intestine tissue than those that do not depend so heavily on rapid acceleration for prey capture. Apart from the small intestine, the stomach size is also important, for this not only involves the mass of the organ itself, but also determines the weight of food that a species can consume. We found that a species such as the sparrowhawk which faces selection pressures to minimize body weight does show small stomach mass. This may accentuate the importance of diet quality between raptors. We showed earlier (Barton and Houston 1993) that species with short intestine lengths are less efficient at digestion and can only maintain body weight when fed on prey species of high calorific value. If they also have significantly smaller stomachs, and so can consume a smaller amount of prey, the difference in organ size emphasizes the need to take prey of high energy content to compensate for the lower overall intake. In Strigiformes, proventriculus and small intestine weight (and also length, see Barton and Houston 1994) was greatest in the tawny owl which is the species with the most passive hunting mode compared to the barn owl or long-eared owl (Barton and Houston 1994).

While there appears to be clear associations between predatory strategy and the total weight of the digestive tract, this is not the case for the liver, kidney, and heart. The size of these organs seems to be strictly determined by metabolic body size, and presumably cannot be reduced in mass without seriously impairing tissue function and the fitness of the bird.

The variations that are found with body condition were perhaps to be expected. When animals enter periods of food deprivation, they depend on endogenous reserves of fat and protein to maintain their metabolic requirements. The extent to which tissue from the alimentary tract is depleted, however, is little known. Our finding that species we examined showed very significant losses of tissue when in poor condition demonstrates that gut tissue is widely used as a reserve. Presumably any reduction in gut tissue has a detrimental effect on digestive efficiency, and so birds do not experience this tissue loss unless they have no alternative. The

finding that heart muscle is also significantly lost in birds in poor condition also demonstrates that when birds reach poor body condition even the most vital organs are affected.

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AGE AND SEX DIFFERENCES IN MOLT OF THE MONTAGU'S HARRIER

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Abstract.—Age and sex differences in the timing and pattern of feather molt in Montagu's harrier (*Circus pygargus*) was studied in 184 museum specimens and live birds collected throughout their breeding and wintering ranges. Molt in adults lasted 6–8 mo, starting in May–June in the breeding areas and finishing in January–February on the wintering grounds. Apparently, Montagu's harriers do not suspend molt during migration. Molt of primaries started earlier in adult females than in adult males, which was probably related to their different roles in feeding nestlings during the breeding season, but both sexes finished molt at about the same time. Yearlings started body molt on the wintering grounds and there was a considerable discrepancy in the extent of body molt of yearlings between data obtained from skins and those from live birds. Yearlings attained plumage similar to that of adults after the first complete molt. Timing of flight feather molt in yearlings and second-yr males was similar to that of adults even though they were not engaged in reproduction. Nevertheless, they finished molting earlier than older birds, but this difference was not significant.

Key Words: *Age and sex differences*; Circus pygargus; *Montagu's harrier*; *molt phenology*; *molt rate*.

Diferencias en la muda del aguilucho cerizo con respecto a la edad y al sexo

Resumen.—Se ha estudiado el patrón de muda en 184 aguiluchos cenizos (*Circus pygargus*) (fundamentalmente ejemplares en museos, y algunos individuos vivos), procedentes de todo su rango de distribución, y se analizan las diferencias en fenología de muda debidas a la edad y al sexo. La muda en los adultos dura 6–8 meses, comenzando en mayo–junio en las zonas de cría, y terminando en enero–febrero en los cuarteles de invernada. Los datos disponibles sugieren que los aguiluchos cenizos no suspenden la muda durante la migración. La muda de las primarias comienza antes en las hembras adultas que en los machos adultos, lo que probablemente está relacionado con la diferente contribución de los sexos a la alimentación de los pollos, pero ambos sexos terminan más o menos al mismo tiempo. Los individuos de primer año comienzan la muda corporal en las áreas de invernada. Encontramos divergencias importantes en el grado de muda corporal de los individuos de primer año, entre los datos procedentes de ejemplares de museo y datos procedentes de observaciones de campo. Se discuten las posibles razones de esta divergencia. Al final de la primera muda completa, los individuos de primer año adquieren un plumaje similar al de los adultos. El comienzo de la muda en los individuos de primer año y en los machos de segundo año es similar a la de los adultos, aunque estos grupos de edad no se reproducen. Sin embargo, parecen terminar la muda antes que los individuos de más edad, aunque las diferencias no son significativas.

[Traducción de author]

Feather molt, reproduction, and migration are three of the more energetically costly components of avian life history. Molt is usually timed to minimize peaks in energy demands during either reproduction or migration, and the duration and extent of molt is constrained by the energy invested in either of the latter two factors (Pietianen et al. 1984). If there are differences between the sexes in their relative contributions towards breeding, they may be reflected in sexual differences in molt. Likewise, age-related differences in molt may be expected between individuals that have not yet entered the breeding population, and this should be especially prominent in long-lived species with delayed sexual maturation.

Relatively little is known about molt in diurnal birds of prey, when compared with that of other bird orders. Large raptors such as eagles and vultures do not undergo a complete molt every year,

but have several foci in the primaries where primaries are molted sequentially (Stresemann and Stresemann 1966, Houston 1975, Edelstam 1984, Bortolotti and Honeyman 1985). In so doing, they avoid excessive raggedness in the wings, which would impair the lift necessary for flight. In contrast, small accipitrids such as hawks usually have one complete molt a year, replacing the primaries from the innermost to the outermost feathers, and the secondaries from three foci (Miller 1941, Piechocki 1955, Stresemann and Stresemann 1966).

The Montagu's harrier (*Circus pygargus*) breeds throughout Europe (wintering in Africa) and the Asian/Russian steppes (in the Indian subcontinent). The molt of Montagu's harrier has never been previously described in detail. Here, we use museum skins (collected throughout its range) and field data from Madrid (Spain) and Sénégal (Africa) to describe the patterns of molt in this species, the differences in timing and duration of molt between males and females, and the acquisition of adult body and flight feathers by yearlings.

METHODS

Sources of Data. Data were recorded from 166 specimens from the Natural History Museum, Tring, UK (28 female yearlings, 31 male yearlings, 36 adult females, 71 adult males), 10 skins from the Museum of Natural History, Madrid (three adult females, seven adult males), three skins of adult males from the Collection Hagi Botti, OR-STOM Station, M'bour, Sénégal, and five breeding birds trapped alive in Madrid (two adult males, three adult females).

Field observations of yearlings in breeding areas in Spain were also used for comparison. All yearlings could be identified by the presence of uniformly dark secondaries characteristic of juvenile Montagu's harriers. Males change their iris color from brown to uniformly pale yellow before they are 3–4 mo old. Females do not attain yellow irides until they are 3–4 yr old, although they might have various degrees of yellow spotting before that. We used eye color to sex birds in juvenile plumage when possible.

Molt Scores. Molt of individual remiges and rectrices was scored from 0–5, following Ginn and Melville (1983), where 0 represents an old feather, and 5 a fully-grown, new feather. The intermediate values (1–4) represent progressions of feather growth. Throughout this study, primaries are numbered from 1 (the innermost) to 10 (the outermost), and the secondaries, including the tertials, are numbered from 1–13 (1 being the outermost). Molt for the vestigial outermost primary (P11) was not recorded. A Primary Molt Score (PMS) was calculated for each bird as the sum of the molt scores of the 10 primaries in one wing, and PMS ranged from 0–50 (Ginn and Melville 1983). When the PMS differed between wings of the same bird, an average of the two scores was

used in analyses. Similarly, we calculated a Secondary Molt Score (SMS, range 0–65), and a Tail Molt Score (TMS, range 0–30) for each bird.

We determined the order in which secondary feathers or tail feathers were molted by calculating the accumulated scores for each numbered feather and ranking each according to its accumulated score. Variations between wings in the order of secondary molt were recorded, but the total score was not significantly different between wings (Mann-Whitney; $W_{120,120} = 14475$, $P = 0.97$). Molt of tail feathers was nearly always symmetrical. Thus, we combined values from both sides for each individual. Primaries were molted sequentially, so we did not calculate accumulated scores for them.

The extent of body molt in yearlings was categorized for each body tract (head, mantle, coverts, breast, and belly) on a four-point scale: 0 (no molt), 1 (very few new feathers present), 2 (mixed new and old feathers), and 3 (molt finished or nearly finished).

Raggedness Scores. An index of raggedness (Haukioja 1971) was calculated for each feather tract (primaries, secondaries, and tail), using the sum of values in each feather of the tract. Each feather was scored with values ranging from 0–4 according to their molt score, where 0 indicated a feather of full length (whether old or new), 4 indicates a feather at the first stage of growth (molt score 1), 3 a feather with molt score 2, 2 a feather with molt score 3, and 1 a feather with molt score 4. For each individual, the sum of raggedness scores from both sides (left and right) of each tract was used as an overall index of raggedness.

Data Analysis. Differences in the molt scores between males and females and age classes were analyzed with nonparametric statistics (Mann-Whitney test). Variations in the timing of secondary molt related to primary molt were analyzed with linear, parametric analysis.

Since several of the skins were dated only to month and not to day of capture, we analyzed data by month This helped to account for latitudinal differences in phenology between birds coming from different regions because breeding phenology in the Montagu's harrier varies on average less than a month between southern and northern Europe (Arroyo 1995). Initially, data for birds from Europe (west of Ural mountains) and data for birds that had been collected in India (presumed to breed in the central Asian steppes) were analyzed separately. This avoided potential differences in phenology between both areas, since no data on timing of breeding for the Asian populations of Montagu's harrier were available. No significant differences in molt scores were found between birds from both regions for equivalent months (Mann-Whitney; $W_{21,10} = 319.0$, $P = 0.47$), so they were combined for subsequent analyses.

RESULTS

Molt in Adults. Adult males and females started molting on the breeding grounds in May–June, and finished molting on the wintering grounds in January–February (Fig. 1). Primary molt was completed in 6–8 mo. Females started molting primaries before males, but both sexes finished at about
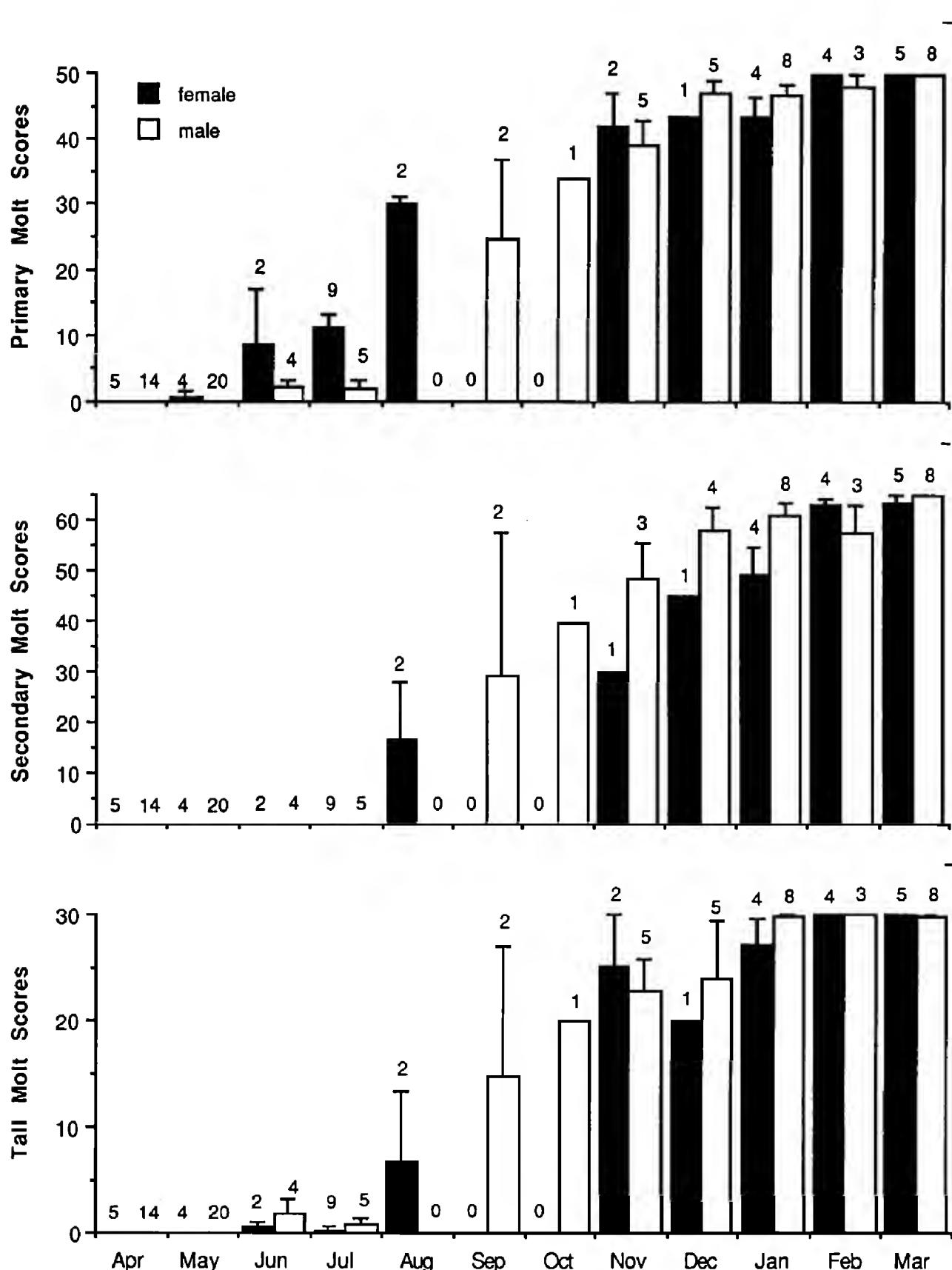
Figure 1. Molt phenology of flight feathers in adult Montagu's harriers. Histograms represent the mean (±SE) primary, secondary and tail molt scores throughout the year for both males and females. Sample size (number of individuals) is given above the histograms.

the same time (Fig. 1). The mean PMS for the breeding months (April–July) was significantly lower in males than in females (Mann-Whitney; $W_{20,43}$ = 816.5, P = 0.0009), but the means were similar in November–February (Mann-Whitney; $W_{11,21}$ = 185.5, P = 0.88). Accordingly, the slope of the regression of PMS vs month was higher for males (5.36) than for females (5.01).

Both males and females started molting secondaries in August–September, and finished at the same time that primary molt finished (Fig. 1). Males started molting secondaries at a significantly earlier stage of primary molt than females did (GLM SMS = PMS + Sex; $F_{1,117}$ = 1956.5, P = 0.0001 for PMS; $F_{1,117}$ = 12.60, P = 0.001 for Sex; Fig. 2). The pattern of secondary molt was highly
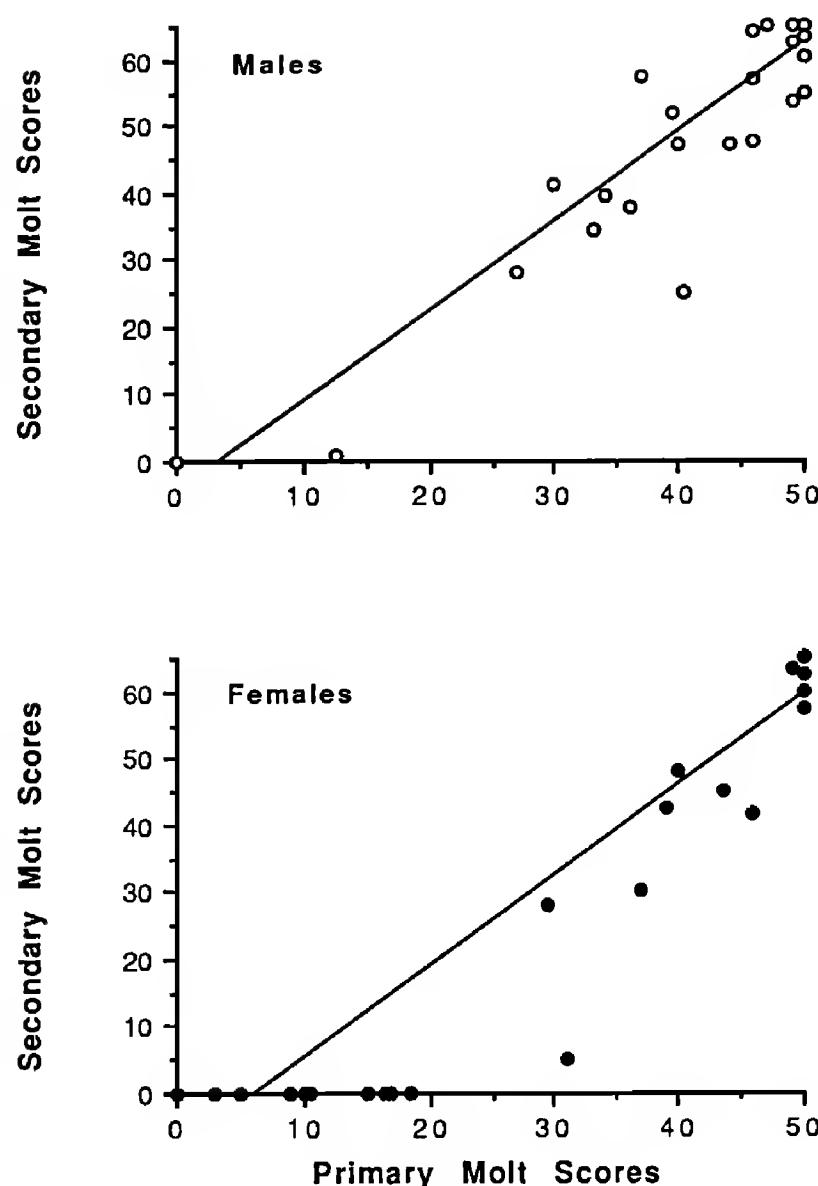
Figure 2. Onset of secondary molt in relation to molt of primary feathers: correlation between secondary molt scores and primary molt scores in adult male ($N = 79$) and female ($N = 40$) Montagu's harriers.
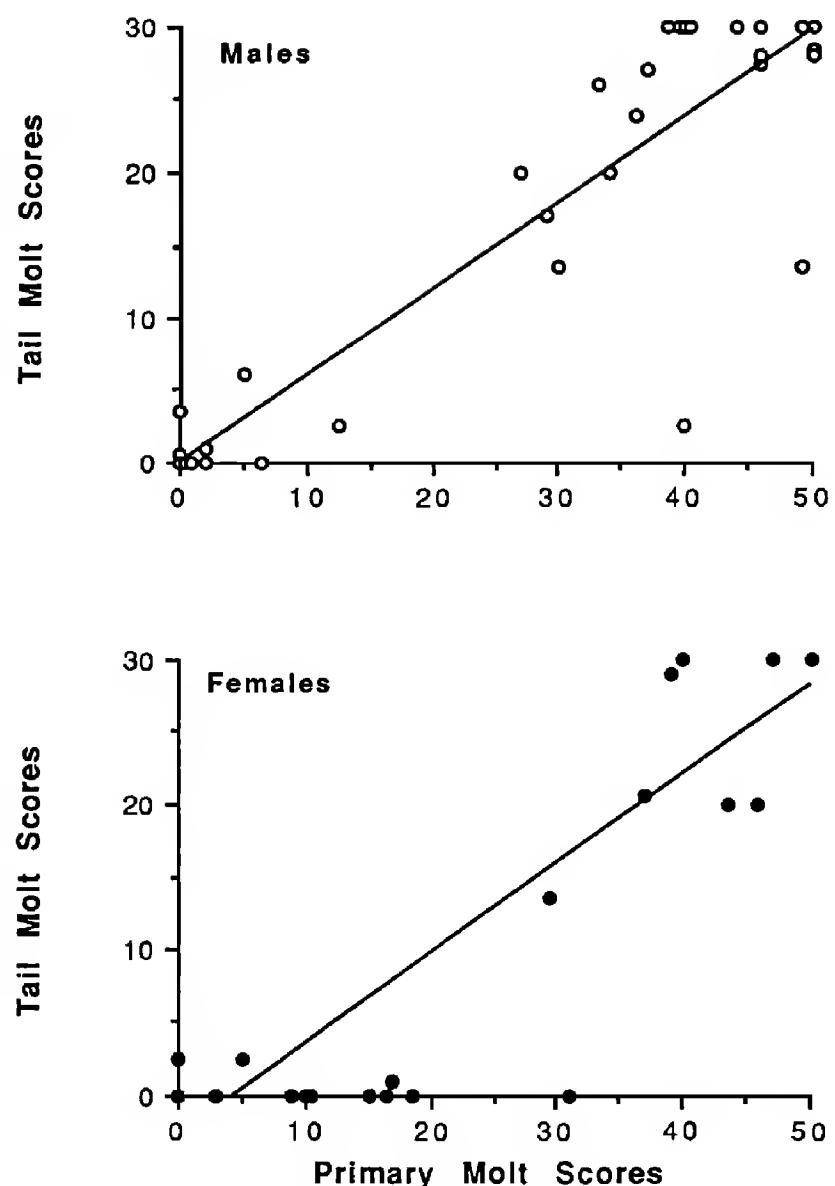
Figure 3. Onset of tail molt in relation to molt of primary feathers: correlation between tail molt scores and primary molt scores in adult male ($N = 79$) and female ($N = 40$) Montagu's harriers.

variable among individuals in relation to the order in which feathers were replaced. The relative order of the accumulated molt scores of each feather (all birds combined) was as follows: for females ($N = 40$): S1 (accumulated score = 180), S5/S11 (165), S2/S13 (160), S4 (155), S12 (150), S10 (146), S9 (130), S3 (123), S6 (120), S7 (115), S8 (108); for males ($N = 79$): S1 (319), S5/S12 (315), S11 (308), S13 (307), S2 (302), S10 (295), S9 (291), S4 (272), S3 (250), S6 (242), S7 (220), S8 (218). These results indicated that two molt foci existed at S1 and S5, and molt at both foci started nearly simultaneously. Another molt center was located in the tertials (S11–13), which were molted at the time, or shortly after the outer secondaries had started to molt. Males seemed to molt the tertials as soon as molt in the outer secondaries had started, while females seemed to molt them more slowly. The order in which tertials were molted did not seem to

follow a fixed pattern. In general, molt was ascendant from S1 and S11 (the outermost tertial), and appeared to be centrifugal from S5. Data from D. Forsman (in litt.) suggests that molt from S5 is ascendant, given that he found S4 to be one of the last secondaries to be molted. However, we found S4 to be one of the earlier molted secondaries in females and it was not the last secondary to be molted by males.

Molt of tail feathers started about June and finished about January (Fig. 1). As with secondaries, males started molting tail feathers at a significantly earlier stage of primary molt than did females (GLM TMS = PMS + Sex; $F_{1,119}$ = 1268.6, P = 0.0001 for PMS; $F_{1,119}$ = 8.15, P = 0.005 for Sex; Fig. 3). The order in which feathers were molted was, as with secondaries, variable but a general pattern was clear from the accumulated molt scores. Molt of tail feathers in females usually started with

the central pair (accumulated molt score of 175), followed by the fourth (166), sixth (161), third (156), fifth (148) and, finally, the second (132) (N = 40). Males had a similar molt pattern, but the sixth pair was the first one to be replaced. The relative order was thus T6 (accumulated score 332), T1 (328), T4 (316), T3 (314), T5 (308) and T2 (294). As in the primaries and secondaries, tail molt seemed to occur more rapidly in males than in females, and the variation in values of accumulated TMS among feathers was lower in males than females. The difference between the highest and the lowest accumulated score was 12% in males and 30% in females which suggested that males molted a greater number of tail feathers at any one time than females.

Primary feathers were most ragged between November–January among females and in June among males. Degree of raggedness in secondaries and tail feathers was generally low throughout the molt cycle in both sexes (Fig. 4). On average, males had higher values of raggedness for all flight feather tracts than females, but differences between the sexes were not statistically significant (Mann-Whitney; $W_{40,80}$ = 2598.5, 2365.0 and 2321.5, P = 0.82, 0.65 and 0.23 for primaries, secondaries, and tail feathers, respectively). The accumulated score of raggedness for all tracts combined peaked for males at values ranging from 23–32 in September–October, while values for females peaked at 25 in November. However, no data existed for females for September and October.

Molt in Yearlings. We recorded no body molt in birds collected in October or November, although sample size was small (N = 3). A small percentage of birds of both sexes started body molt in December, usually in the region of the crop, and males also on the rump (Table 1). Central tail feathers were also replaced in about 25% of birds of both sexes. However, the extent of molt completed before spring migration was limited in both sexes. The proportion of yearlings with some degree of body molt increased throughout the spring and summer. Although a few yearlings had not started molting any body feather tracts by July or August, many started but had not completed molt in most tracts by that time. Yearling males that attempted to breed in Madrid were at the same stage of molt as those that did not breed (B. Arroyo unpubl. data). Furthermore, a yearling male that bred in 1994 had molted only the central tail feathers and part of the feathers in the region of the crop when

it arrived on the breeding grounds in Spain. Body molt of yearlings finished in October–November. Males retained some juvenile feathers in the ear coverts and in the nape, which allowed aging of second-year individuals in the hand.

There was a considerable discrepancy between the extent of body molt in yearlings recorded during field observations and from museum specimens. Detailed plumage observations of 30 yearlings (21 males and nine females) were made in breeding areas in Spain. Yearling males showed more advanced body molt than did museum specimens collected at the same time of year and for birds observed in the field, the head, breast and belly tracts, respectively, showed evidence of molt in 91%, 62% and 62% of individuals, compared to 43%, 29% and 14% of museum specimens (Table 1). The extent of molt recorded was also greater for individuals observed in the field. In contrast, yearling females observed in the field showed less advanced body molt than museum specimens. Only 33% of the females observed in the field showed molting in the crop, breast, and belly, compared to over 63% of the museum specimens (Table 1). This discrepancy might be an artifact of the relatively small number of specimens of yearlings, but it may well be a consequence of the relative visibility of newly-molted, grey plumage in yearling males, leading to overestimation of the extent of molt when recorded in the field. In the latter case, the similarity between old and new plumage in females would lead to an underestimation of the extent of body molt in that sex. Furthermore, yearling males showing little or no molt may have been misidentified as females in the field, or more likely, left unsexed due to apparently conflicting characters such as small size but no visible male plumage features.

Primary molt in yearlings apparently started at the same time as that of adults (Fig. 5) and molt scores were similar between both age groups in April–July (Mann-Whitney; $W_{20,12}$ = 194.5, P = 0.90 for females; $W_{43,10}$ = 284.0, P = 0.64 for males). The completion of primary molt in October–February also appeared to be similar for yearlings and adults, however sample sizes were very small for the yearling group (Mann-Whitney; $W_{22,4}$ = 57.5, P = 0.83 for males; insufficient data for females to allow statistical analysis).

Molt of secondary and tail feathers followed the same pattern, and occurred at the same time in relation to primary molt, as in adults. Juvenile
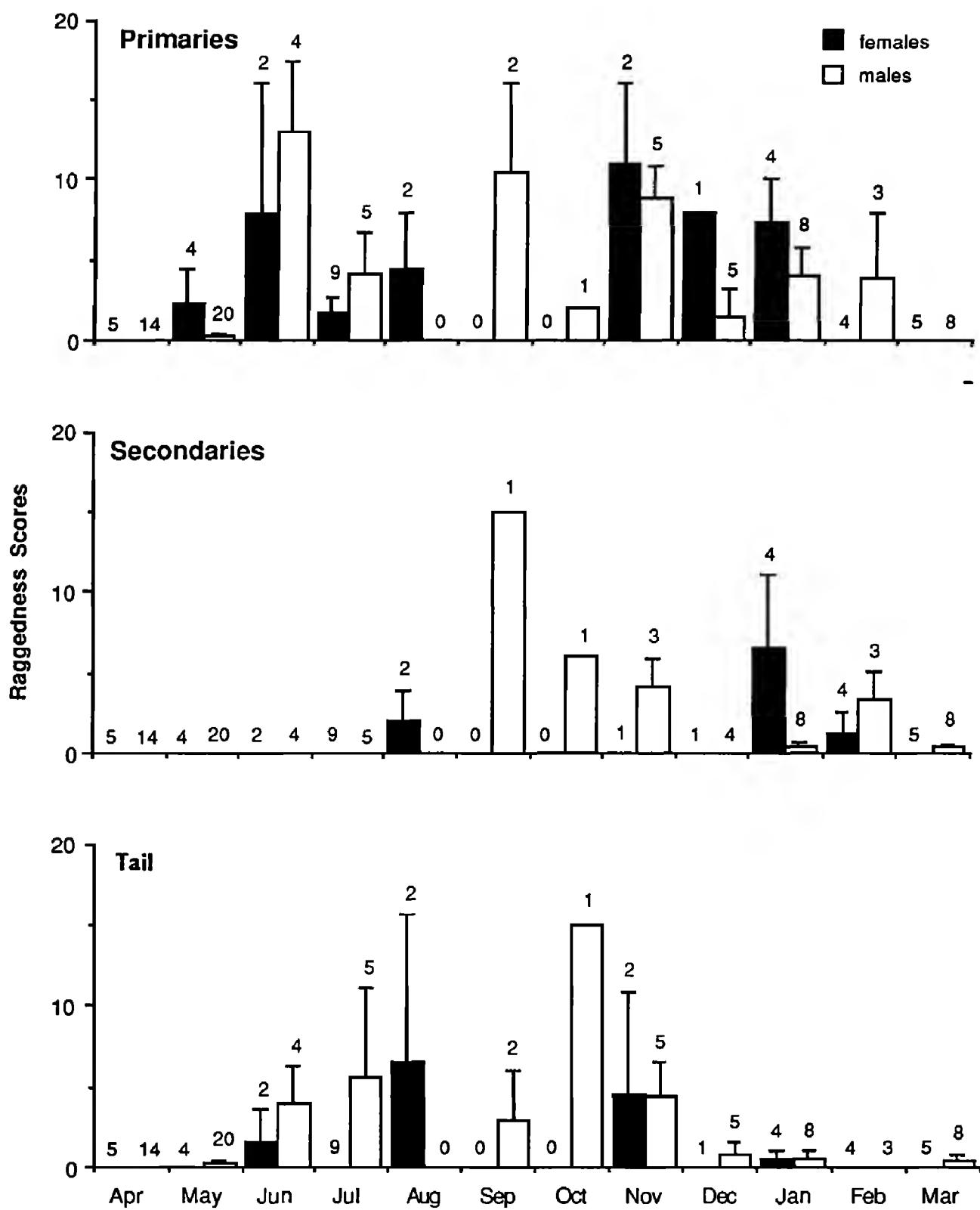
Figure 4. Degree of raggedness in flight feather tracts throughout the year in adult Montagu's harriers of both sexes. Histograms represent the mean (±SE) raggedness scores for primaries, secondaries and tail feathers. Sample size (number of individuals) is given above the histograms.

feathers were replaced by feathers similar to those of adults, only slightly darker. Thus, after the first complete molt, yearlings were indistinguishable from older birds in the field as confirmed by observations of dark-looking plumage in known-age wing-tagged individuals ≥3 years old.

Molt in Second Year Males. Fourteen males in adult plumage could be identified as second-yr males by the presence of a few unmolted, juvenile feathers on the nape or ear coverts. Second-yr males started molt at the same time as older males, and from May–July the scores for the two age-classes were similar (Mann-Whitney; $W_{34,9} = 231.0$, $P = 0.13$). However, in November–February, second-yr males had higher PMS than older males, and the difference approached significance (Mann-Whitney; $W_{16,4} = 60.5$, $P = 0.08$). Similarly, second-yr males had higher values of SMS than older males

Table 1. Percentage of yearling specimens of Montagu's harriers in which molted feathers were present in different feather tracts. Figures in brackets show the mean score of the individuals in molt (1 [only a few feathers]–3 [molt complete]). N = number of individuals; LC, MC, GC = lesser, middle, and greater coverts, respectively; CTF = central tail feathers; OTF = other tail feathers.

DATE	N	HEAD	CROP	BREAST	BELLY	LC/MC	GC	MANTLE	RUMP	CTF	OTF
Males											
Dec–Jan	9	0	33.3 (3.0)	22.2 (2.0)	0	11.1 (2.0)	0	0	33.3 (3.0)	11.1 (2.0)	0
Feb–Mar	3	33.3 (1.0)	66.6 (1.0)	0	0	0	0	0	66.6 (3.0)	0	0
Apr–May	7	42.8 (1.3)	85.7 (1.8)	28.6 (1.5)	14.3 (2.0)	42.8 (2.0)	14.3 (1.0)	28.6 (1.5)	57.1 (2.0)	57.1 (3.0)	14.3 (2.0)
Jun–Jul	3	66.6 (1.0)	100 (2.0)	66.6 (2.0)	33.3 (1.0)	0	0	0	66.6 (1.5)	100 (2.0)	66.6 (2.0)
Aug	2	50.0 (1.0)	50.0 (3.0)	100 (2.5)	100 (2.0)	100 (1.5)	100 (2.5)	50.0 (1.0)	100 (3.0)	50.0 (3.0)	50.0 (2.0)
Females											
Dec–Jan	6	0	16.7 (2.0)	16.7 (2.0)	16.7 (2.0)	0	0	0	0	50.0 (2.7)	0
Feb–Mar	5	0	40.0 (1.0)	40.0 (1.0)	20.0 (1.0)	0	0	0	20.0 (3.0)	20.0 (3.0)	20.0 (2.0)
Apr–May	8	37.5 (2.0)	87.5 (1.8)	62.5 (1.5)	62.5 (2.2)	25.0 (1.5)	0	0	25.0 (1.0)	37.5 (3.0)	0
Jun–Jul	3	66.6 (1.5)	100 (2.6)	66.6 (2.5)	66.6 (2.5)	66.6 (2.5)	33.3 (3.0)	0	66.6 (1.5)	100 (2.0)	100 (2.0)

during same period, although the difference was not significant (Mann-Whitney; $W_{15,4} = 55.0$, $P = 0.14$), perhaps due to small sample sizes.

DISCUSSION

Molt started in the breeding season (June–July) and finished during the winter months approxi-mately 6–8 mo later, indicating that the molt period in Montagu's harrier is long compared to that of nonmigratory raptors of comparable body size such as northern goshawks (*Accipiter gentilis*; Reading 1990), sparrowhawks (*Accipiter nisus*; Newton and Marquiss 1982), and little banded goshawks (*Accipiter brevipes*; Schmitt et al. 1981). We could
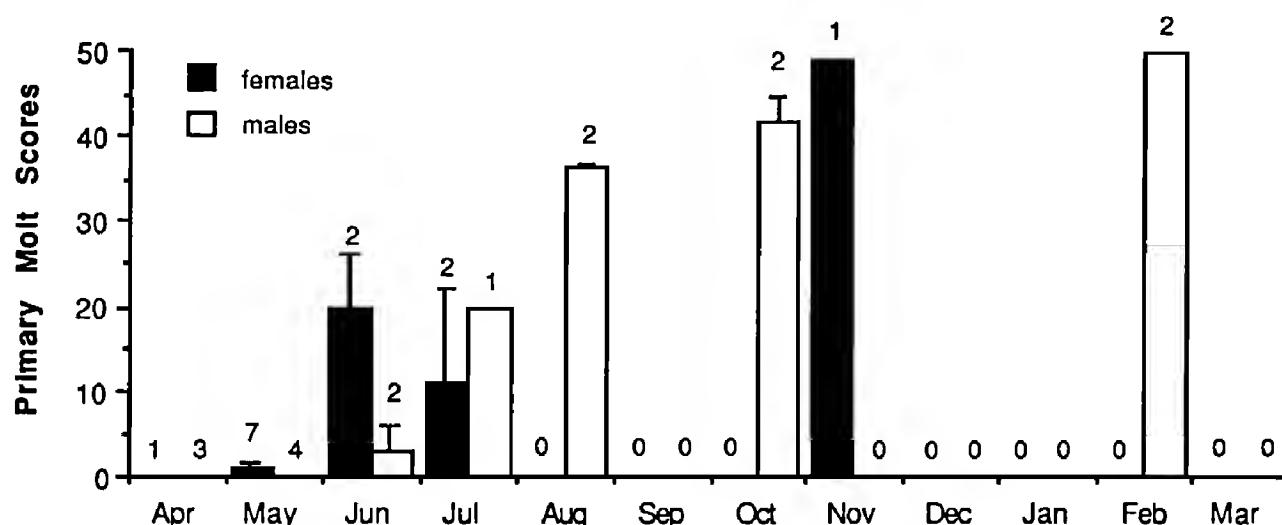
Figure 5. Molt phenology of primary feathers in yearling Montagu's harriers. Histograms represent the mean (± SE) primary molt scores throughout the year for both males and females. Sample size (number of individuals) is given above the histograms. Secondaries and tail feathers, as in adults, are molted in the interval when primaries are molted.

not confirm that birds suspended molt during the migration, as no birds were collected on the migratory route. However, molt scores of birds collected in August–October in either breeding or wintering areas together with high molt scores of the birds collected in November on the wintering grounds, suggested that at least some birds continued to molt while migrating. The duration of the autumn migration is unknown, but may be in excess of 1 mo given the average dates of departure from the breeding grounds (Studinka 1941, Petrement 1968, Perez Chiscano and Fernandez Cruz 1971, Kjellen 1992, Martelli and Parodi 1992, Arroyo 1995), and dates of arrival in wintering areas (Morel and Roux 1966). Migratory flight of harriers seems to be slow and generally at relatively low altitudes. They combine flapping and gliding and hunting along the way (Brown 1976, Ali and Ripley 1978). This mode of migration may allow harriers to continue molting slowly while migrating as they are not soaring birds, for which gaps in the wings would represent higher energetic costs. Piechocki (1955) observed molt in a single captive pallid harrier (*Circus macrourus*). Each tail feather took 45 d to grow completely. Presumably, the primaries would take longer to grow especially from P5 onwards. If single primaries are not shed until growth of the previous one is nearly finished, harriers may keep molting at a slow rate during the migration instead of suspending molt.

As in goshawks and sparrowhawks (Newton and Marquiss 1982, Reading 1990), molt of primaries in Montagu's harrier was spread throughout the entire molt cycle. Secondaries were molted later in the season, but finished at approximately the same time as the primaries. In raptors, molt of secondaries and especially of tail feathers, occurs more quickly than that of primaries (Newton and Marquiss 1985, Underhill 1986, Schmitt et al. 1987). In the Montagu's harrier, molt of the secondaries either did not start, or was not apparently advanced before autumn migration. Secondaries provide much of the lift required for flight (Newton and Marquiss 1982), so it may be especially important to minimize gaps in these feathers for long-distance migration. In accordance with this hypothesis, raggedness scores in the secondaries were always low in comparison with those of primaries.

Males started molting later than females. A similar temporal difference in the onset of molt between sexes has also been documented in sparrowhawks (Newton and Marquiss 1982) and northern

harriers (*Circus cyaneus hudsonius;* Schmutz and Schmutz 1975). Breeding birds must divide their energy between two energetically costly tasks: breeding and molting. In Ural owls (*Strix uralensis*), breeding delays molt and the number of molted feathers is inversely related to energy expended during the previous breeding season (Pietiainen et al. 1984). Therefore, in species in which males do most of the hunting in the breeding season, a sexual dimorphism of molt initiation is expected. In Montagu's harrier, females contributed less than 15% to the feeding of nestlings and fledglings (Arroyo 1995). Females can start molting during incubation, when their energy expenditure is less than that of hunting males. The onset of molt in female sparrowhawks was related to the date they started laying (Newton and Marquiss 1982), but such a relationship was not found in northern harriers (Schmutz and Schmutz 1975) or Swainson's (*Buteo swainsoni*) or ferruginous (*B. regalis*) hawks (Schmutz 1992). Most female Montagu's harriers observed in Madrid appeared to have started molt soon after incubation began (B. Arroyo unpubl. data), but it is not known whether the timing of molt was correlated with timing of egg laying.

As in the northern harriers (Schmutz and Schmutz 1975), male Montagu's harriers apparently molted at a faster rate than females. Female feathers are longer (Nieboer 1973), and may take slightly more time to reach their full length. However, in sparrowhawks in which sexual dimorphism is much greater than in Montagu's harriers, difference between the sexes in the duration of molt is related to the interval between shedding feathers, not the time that each individual feather takes to grow to its full extent (Newton and Marquiss 1982).

Both sexes differed slightly in the order which secondary and tail feathers were molted. Females molted secondaries 2 and 4 before finishing the tertials, whereas molt of the tertials proceeded at a faster rate in males. Additionally, males molted the outermost tail feathers before any other. The adaptive reasons (if any) for these different strategies are unclear, and the apparent pattern might be an artifact of sample size used in our study.

Yearlings do not usually have the same energetic costs of adults, and their plumage is usually of poorer quality. Thus, it would be expected that they start replacing their flight feathers earlier than adults. This has been found to be true of yearling sparrowhawks (Newton and Marquiss 1982), cap-

tive goshawks (Reading 1990), and pallid harriers (*Circus macrourus*; Piechocki 1955). In this study, yearlings did not appear to start molt significantly earlier than adults. This again may have been due to sample size limitations; however, younger birds are less experienced hunters than adults, so they may be under higher nutritional stress, especially individuals that have undergone spring migration. Some yearlings summer in Africa and apparently they replace remiges faster than birds returning to the breeding grounds (D. Forsman, in litt.). In this study, the highest PMS among yearlings early in the cycle were shown by females that bred (shot while incubating), possibly because they were fed by males, and were in better condition than other yearlings (of either sex) that had to hunt for themselves. On the other hand, yearlings seemed to complete molt before adults although the differences were not significant. Second-yr males, which are probably nonbreeders (given that most males do not start breeding until the third year; Cramp and Simmons 1980), appeared to finish molt before older males. This suggests that nonbreeding birds molted at a faster rate. Alternatively, different age groups might have different migration strategies, which in turn might influence molt if yearlings migrate at a slower rate. If young birds make more stopovers to feed, they might be able sustain a higher rate of molt in flight feathers as has been shown in steppe buzzards (*Buteo buteo vulpinus*; Gorney and Yom-Tov 1994).

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SHORT COMMUNICATIONS

COMPARISON OF FLEDGING SUCCESS AND SIZES OF PREY CONSUMED BY SPOTTED OWLS IN NORTHWESTERN CALIFORNIA

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Key Words: *California; optimal foraging theory; prey; reproduction; spotted owl;* Strix occidentalis.

Several studies have documented the food habits of spotted owls (*Strix occidentalis;* Forsman 1980, Solis 1983, Forsman et al. 1984, Barrows 1980, 1985, 1987, Thrailkill and Bias 1989, Ward 1990). Only a few studies have investigated the relationship between size of prey consumed and reproductive success (Barrows 1987, Thrailkill and Bias 1989, Ward 1990), but successful breeding has been associated with a greater proportion of large mammalian prey items (>100 g) within the diet of both northern (*S. o. caurina*) and California (*S. o. occidentalis*) subspecies of the spotted owl (Barrows 1987, Thrailkill and Bias 1989). Despite this, Ward (1990) found no significant difference in prey sizes of breeding and non-breeding owls in northwestern California.

Optimal foraging theory predicts that predators consume prey providing the greatest energetic benefit-to-cost ratio (Krebs 1978). More specifically, central place foragers, such as breeding spotted owls, are expected to increase fitness by maximizing rate of energy delivery to the central place, or nest (Orians and Pearson 1979). Thus, consumption of large prey would be expected to yield a greater energetic return than consumption of small prey (assuming costs of capturing large prey is not disproportionate to costs required for small prey capture). As a result, a positive association is expected between prey size (an index of energetic gain) and fledging success (an index of fitness). Theoretically, selection of larger prey should provide parents with an energetic surplus enabling them to meet the increased energy demands associated with producing young. This study was undertaken to determine if the food consumption of breeding northern spotted owls is consistent with the predictions of optimal foraging theory. Proximate explanations, such as prey availability and individual hunting behavior, which may account for observed patterns in prey

consumption and reproductive success, are difficult to assess and were beyond the scope of this study.

Breeding spotted owls were located using standard survey techniques (Forsman 1983) in a 292 km² study area located south of Willow Creek, Humboldt County, California, and in 12 satellite areas located in Mendocino, Humboldt, Trinity, and Siskiyou counties, California (see Franklin et al. 1996 for description of the study area). Both study areas were dominated by mixed evergreen forest and Klamath montane forest vegetation types (Küchler 1977).

Owl pairs were considered successful if they fledged young and unsuccessful if no young fledged. Pellets were collected opportunistically at owl roost sites. Prey were identified and counted from skulls or reconstructed appendicular skeletons, whichever gave the highest count (Forsman et al. 1984). Mean weight of individual prey species was based on Forsman (1980), Solis (1983), and the Humboldt State University reference collection. Prey items were divided into three size classes, based on natural breaks in the sizes of prey taken by northern spotted owls: large prey >269 g, medium prey 80–115 g, and small prey <35 g. Frequency and biomass of each prey type were calculated for successful and unsuccessful pairs of breeding owls and Chi-square analysis was used to compare frequencies of prey size categories in their diets (Ott 1988). Contingency table subdivision was used to isolate significance (Zar 1974).

A total of 672 prey items were identified from 330 pellets collected in 63 known owl territories from April through August 1987–95. Of the total prey items, 418 were collected from territories of successfully breeding owls and 254 were from territories where owls failed to fledge young.

Large prey accounted for the largest proportion of prey biomass eaten by both successful (0.72) and unsuccessful breeding owl pairs (0.55), as well as the highest proportion (0.36) of individual food items taken by successfully breeding pairs (Table 1). Small prey accounted for the highest proportion (0.41) of food items eaten by unsuccessfully breeding owls.

The diet of owls that successfully fledged young dif-

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Table 1. Proportion of prey based on frequency and biomass in the diets of spotted owls relative to fledging success in northwestern California from 1987–95.

	SUCCESSFUL		UNSUCCESSFUL	
SPECIES	FREQUENCY ($N = 418$)	BIOMASS (g) ($N = 54,362$)	FREQUENCY ($N = 254$)	BIOMASS (g) ($N = 26,980$)
Large prey (>269 g)				
Neotoma fuscipes	0.34	0.72	0.22	0.55
Unidentified large prey	0.02	N/A	0.01	N/A
Subtotal	0.36	0.72	0.23	0.55
Medium prey (80–115 g)				
Glaucomys sabrinus	0.26	0.24	0.35	0.38
Eutamias sp.	0.01	0.01	0.00	0.00
Sylvilagus bachmani (juv.)	<0.01	<0.01	0.00	0.00
Unidentified medium prey	0.01	0.01	0.01	0.01
Subtotal	0.28	0.25	0.36	0.38
Small prey (<35 g)				
Arborimus longicaudus	0.08	0.02	0.15	0.04
Clethrionomys californicus	0.02	<0.01	0.05	0.01
Peromyscus sp.	0.11	0.02	0.07	0.02
Microtus sp.	0.01	<0.01	0.02	<0.01
Scapanus sp.	<0.01	<0.01	0.00	0.00
Sorex sp.	<0.01	<0.01	<0.01	<0.01
Lasionycteris noctivagans	<0.01	<0.01	0.00	0.00
Reithrodontomys megalotis	0.02	<0.01	0.01	<0.01
Unidentified small prey	0.04	N/A	0.03	N/A
Unidentified small bird	0.03	N/A	0.03	N/A
Unidentified insect	0.03	N/A	0.04	N/A
Subtotal	0.35	0.04	0.41	0.07
Total	1.00	1.00	1.00	1.00

fered significantly in terms of prey size from the diet of owls that failed to fledged young ($\chi^2 = 14.78$, df = 2, $P < 0.001$). No significant difference was detected between successful and unsuccessful owls relative to the number of medium and small prey found in pellets ($\chi^2 = 0.47$, df = 1, $P = 0.49$). However, a significant difference was detected when comparing successful and unsuccessful owls relative to large and pooled medium/small prey ($\chi^2 = 14.28$, df = 1, $P < 0.001$).

My analysis indicated that spotted owls which successfully fledged young ate significantly more large prey items than unsuccessful owls. Spotted owls consumed about 40 g of food per feeding period so large prey items appeared to provide owls with a large (239 g), efficiently transported food source with each prey capture. Unsuccessfully breeding owls consumed more medium and small prey than large. Transportation of prey back to a central place, such as a nest, places increased energetic demands on a predator (Orians and Pearson 1979). Thus, capture of medium and small prey may result in an energetic trade-off due to decreased energetic returns. Ultimately, this would cause spotted owls to suspend breeding in a given year if food fell below levels

necessary to maintain adult energy requirements (Alcock 1993).

Bull et al. (1989) found that male great gray owls (*Strix nebulosa*) maximized the return for their hunting energy expenditure by eating smaller prey at the point of capture and taking larger prey back to the nest. Such preferential prey delivery to nests can bias results of dietary studies. I do not consider this to have been the case in my study because pellets collected at roosts contained remains of all prey captured throughout the nocturnal hunting period.

My results support optimal foraging and central place foraging theories as ultimate explanations for the observed positive relationship between large prey size and fledging success. Future investigations of proximate explanations for their tendency to hunt larger prey will contribute to our understanding of the influence of prey size on spotted owl fledging success.

RESUMEN.—Las dietas de *Strix occidentalis* fueron comparadas en relación al éxito de volantones, investigando el tamaño de las presas (grande, >269 g; mediana 80–115 g; pequeña, <35 g) encontradas en 330 pelletts colecta-

dos en 63 territorios de búhos en el noroeste de California. Seiscientos setenta y dos categorías de presas fueron identificadas. Las egagrópilas colectadas en territorios de búhos con juveniles exitosos contenían significativamente una mayor proporción de presas grandes que las egagrópilas de parejas sin volantones exitosos. Las dietas de búhos reproductivos exitosos y no exitosos no tenían diferencias significativas relacionadas con la frecuencia de presas medianas y pequeñas. Esta relación es consistente con otros estudios de *S. occidentalis* y podría estar relacionado al alto contenido de enregía de grandes presas.

[Traducción de Ivan Lazo]

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DIET OF LONG-WINGED HARRIER (*CIRCUS BUFFONI*) IN SOUTHEASTERN BUENOS AIRES PROVINCE, ARGENTINA

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The long-winged harrier (*Circus buffoni*) is widespread in South America ranging from Venezuela to Chubut Province in Argentina, occasionally reaching as far south as Tierra del Fuego (Nores and Yzurieta 1980) and central Chile (del Hoyo et al. 1994). Found throughout Argentina in open fields, grasslands, savannas, marshes, wetlands and ponds from sea level to 690 m elevation (Canevari et al. 1991, De la Peña 1992, del Hoyo et al. 1994), it is most abundant in the Chaco-Pampean zone of Argentina, Uruguay and Brazil (Grossman and Hamlet 1964).

Studies of the long-winged harrier have focused mainly on its nesting biology (Narosky and Yzurieta 1973), and there is only descriptive information on its diet (De la Peña 1985, Canevari et al. 1991, López 1993, del Hoyo et al. 1994) and hunting habitats (Narosky and Yzurieta 1973, 1988, De la Peña 1985). The objective of this study was to determine the diet and niche breadth of long-winged harriers in the Pampas zone of Argentina.

Our study was conducted in the Laguna de los Padres Integral Reserve (37°56'S, 57°44'W) 16 km west of Mar del Plata City, Buenos Aires Province. The reserve covers a 680 ha area with low hills and plains. Mean annual temperature is 13.8°C and mean annual precipitation is nearly 5 cm. Harriers selected for study were located in a 87 ha area within the reserve called the "El Curral" Intangible Reserve Zone. It consists of a mosaic of shrubland habitat with native "curro" (*Colletia paradoxa*), exotic blackberry (*Rubus ulmifolius*) and modified Pampean grassland comprised of *Stipa* spp., *Bothriochloa* spp., *Conium* spp. and *Carduus* spp. (Cabrera and Zardini 1978). Cultivated fields, pastures, tree plantations (mainly *Eucalyptus*) and suburban zones surround the study area, and it is only 400 m from Laguna de Los Padres, where there is a large concentration of breeding, aquatic birds including brown-hooded gulls (*Larus maculipennis*), white-faced ibises (*Plegadis chihi*), snowy egrets (*Egretta thula*), cattle egrets (*Bubulcus ibis*), black-necked swans (*Cygnus melanocorypha*) and coots (*Fulica* spp.).

During springs and summers of 1992–93 and 1993–94, pellets and prey remains were collected every 5–6 d at nest sites, plucking stations and roosts of breeding pairs of long-winged harriers. Bird, mammal and insect remains were identified based on bones, feathers, bills,

hair, dentaries and exoskeletons, and compared with specimens in collections of Museo de Ciencias Naturales de La Plata, Museo de Ciencias Naturales "Lorenzo Scaglia" de Mar del Plata and Laboratorio de Vertebrados, Facultad de Ciencias Exactas y Naturales-Universidad Nacional de Mar del Plata. All remains in a collection were lumped and prey items were identified using known remiges, rectrices, bills and bones of birds and fur, skull parts and feet of mammals. This procedure minimized the possibility of overcounting numbers of individuals of each species (Reynolds and Meslow 1984, Marti 1987). Most prey were identified to the species level.

Adult bird and mammal weights were obtained from the literature (Fiora 1933, De la Peña 1987, Salvador 1988, 1990, Navas 1991, Camperi 1992) and unpublished data of Kittleim, Comparatore and Barbini, and in the Museo de Ciencias Naturales "Lorenzo Scaglia" de Mar del Plata. Following Pavez et al. (1992) and Jiménez (1993), a weight of 1 g was assigned to each insect prey species. When the sex of prey could not be determined, the mean weight of males and females was used. Geometric mean (±SE) weight for total prey was calculated (Marti 1987) and Levins' index of niche breadth (Marti 1987) was calculated as:

$$B = \frac{1}{\sum\limits_{i=1}^{n} p_i^2}$$

where p_i is the proportion of individuals in each prey category. B varies from 1 to N with N being the number of prey categories. If prey are equally common in all categories, then $B = N$; if all prey belong to only one category, $B = 1$.

We located 4 and 2 pairs of breeding harriers in 1992–93 and 1993–94, respectively, and made a total of 46 pellets and 28 prey remains. Pellets averaged 41.8 ± 10.4 mm (±SD) in length and 17.9 ± 2.9 mm wide ($N = 38$). A total of 98 prey items was identified from 3 taxonomic classes including 22 vertebrate species and 2 insect orders (Table 1). Levins' Index (B) of niche breadth was 7.9 ($N = 25$, minus unidentified prey).

Birds accounted for 79.5% of the total prey items, followed by mammals (17.5%) and insects (3%). Among birds, passerines were the most common (61%) prey remains found. Most passerines belonged to the Emberizidae (40%), with rufous-collared sparrow (*Zonotrichia capensis*) the most abundant species. Fringillids, mainly hooded

Table 1. Percent frequency of prey items, weight of individual prey and total percent biomass of prey in the diet of breeding long-winged harriers in southeastern Buenos Aires Province, Argentina. Percentages based on a total of 98 prey items.

PREY	% FRE-QUENCY	ADULT WEIGHT (g)	% TOTAL BIOMASS
Birds	79.5		68.6
Tinamidae			
Nothura maculos	2.0	240	7.0
Nothura maculosa (egg)	2.0	20	0.7
Threskiornithidae			
Plegadis chihi	3.0	450	19.8
Anatidae			
Anas sp. (chick)	3.0	80	3.5
Rallidae			
Rallus sanguinolentus	1.0	162	2.4
Columbidae			
Columba picazuro	2.0	213	6.2
Zenaida auriculata	3.0	128	5.7
Furnariidae			
Phleocryptes melanops	1.0	16	0.2
Mimidae			
Mimus saturninus	1.0	74	1.1
Emberizidae			
Sicalis luteola	5.0	16	1.2
Sicalis sp.	2.0	16	0.5
Zonotrichia capensis	27.5	22	8.8
Unidentified egg	1.0	2	0.1
Icterinae			
Molothrus bonariensis	1.0	62	0.9
Molothrus badius	1.0	53	0.8
Pseudoleistes virescens	1.0	71	1.0
Sturnella superciliaris	1.0	53	0.8
Carduelis magellanica	11.0	15	2.4
Ploceidae			
Passer domesticus	4.0	31	1.8
Unidentified passeriformes	4.0	21[a]	1.3
Unidentified birds	2.0	96[b]	2.8
Mammals	17.5		31.4
Leporidae			
Lepus capensis (young)	6.0	300	26.4
Cricetidae			
Oxymycterus rufus	2.0	70	2.0
Akodon azarae	4.0	21	1.2
Oryzomys flavescens	2.0	17	0.5
Unidentified cricetidae	1.0	36[c]	0.5
Didelphidae			
Monodelphis dimidiata	1.0	16	0.2
Unidentified mammals	1.0	31[d]	0.4
Insects	3.0		<0.1
Coleoptera	2.0	<1.0	<0.1
Odonata	1.0	<1.0	<0.1

[a] Average of the 4 most common identified passerine birds.
[b] Average of all identified birds.
[c] Average of the 3 identified cricetids.
[d] Average of the identified cricetids and Monodelphis dimidiata.

siskin (Carduelis magellanica), made up 11% of the diet. Among mammalian prey, rodents were the most numerous (9%) with Akodon azarae the most common species followed by lagomorphs (6%) and marsupials (1%).

Long-winged harriers preyed on a wide range of prey sizes with weights ranging from a low of 1 g in the case of insects to a high of 450 g in the case of the white-faced ibis. Geometric mean weight of prey was 32.4 ± 11.2 g (±SE). By weight, birds comprised the majority of the prey biomass (68.6%). White-faced ibises contributed the greatest biomass (19.8%) followed by rufous-collared sparrow (8.8%), spotted tinamou (Nothura maculosa, 7%), picazuro pigeon (Columba picazuro, 6.2%) and eared dove (Zenaida auriculata, 5.7%). Mammals comprised 31.4% of the prey biomass with juvenile European hares (Lepus capensis) contributing the largest amount (26.4%). Insect biomass was very low (<0.1%) in the diet.

Our results are similar to those observed for Montagu's harrier (Circus pygargus), marsh harrier (C. aeruginosus) and hen harrier (C. cyaneus), which also prey mainly on birds (González López 1991). During the breeding season, diets of marsh and hen harriers can consist of as much as 70% birds by frequency of occurrence (Schipper 1973, Witkowski 1989, González López 1991, del Hoyo et al. 1994). Several authors (De la Peña 1985, 1992, Canevari et al. 1991) have mentioned that long-winged harriers hunt mainly in wetlands, ponds and marshes. The type of prey in our study was mainly from terrestrial habitats (91%) and was probably related to the fact that cultivated fields, pastures, and tree plantations surrounded the study area.

RESUMEN.—Se estudió la dieta del gavilán planeador (Circus buffoni) durante dos períodos reproductivos en la Reserva Integral Laguna de Los Padres, Provincia de Buenos Aires. El área de nidificación se encuentra en un ambiente arbustivo, circundado por campos cultivados, pasturas, montes, lagunas y ambientes suburbanos. Se analizaron 46 egagrópilas y 28 restos presa, provenientes de seis parejas nidificantes. Se identificaron 98 items presa, correspondiendo el 79.5% a las aves, el 17.5% a los mamíferos y un 3% a los insectos. La amplitud de nicho trófico (B) fue de 7.9 (N = 25). Los paseriformes fueron las presas más consumidas (61%), dentro de las cuales el chingolo (Zonotrichia capensis) y el cabecita negra común (Carduelis magellanica) fueron las especies más frecuentes. La media geométrica del peso de presas consumidas fue de 32.4 ± 11.2 (± ES). En cuanto a la biomasa aportada, las aves y los mamíferos contribuyeron en un 68.6% y 31.4%, repectivamente. La dieta del gavilán planeador mostró similitud con la de otras especies del género Circus.

[Traducción de Author]

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SOCIAL BEHAVIOR OF CAPTIVE FLEDGLING AMERICAN KESTRELS (*FALCO SPARVERIUS*)

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Adult American kestrels (*Falco sparverius*) are highly territorial both on their summer and winter grounds (Smallwood 1987, 1988, Palmer 1988). Sexual segregation of wintering kestrels by habitat has also been reported (Koplin 1973, Mills 1976, Smallwood 1987). Young kestrels already show reversed sexual size dimorphism at fledging, with females being larger than males (Negro et al. 1994). Although adults are aggressive to conspecifics, juveniles are extremely social and brood members engage in social hunting (Varland and Loughin 1992). Juveniles of both sexes gather in groups before fall migration (Cade 1955) indicating that young kestrels may have behavioral mechanisms to integrate in groups. This paper describes the social behavior of captive fledgling American kestrels during the post-fledging dependence period.

METHODS

We examined social interactions within three American kestrel families. Each family was composed of two parents and four young, with sex ratios as follows: 3 females and 1 male in family 1 (FG1); 1 female and 3 males in family 2 (FG2); and 2 females and 2 males in family 3 (FG3). The birds were housed in the same aviary where breeding had taken place (2.00 × 1.30 × 2.00 m) at the Avian Science and Conservation Centre of McGill University, Quebec, Canada. Kestrels were maintained at natural photoperiod and temperature, and food consisted of seven 1-d-old cockerels for each family given at the beginning of each daily observation session.

During observation sessions, behaviors of kestrels were recorded through one-way windows on one side of the aviary. For individual identifications, legs of young were marked with different colors using waterfast color markers. Observations started when all young in each nest had fledged. A total of 90 h (30 h per family) of observations was recorded following a rotating schedule during morning and afternoon hr from 4–19 July 1994.

Ten different behaviors were recorded: **approach** (AP), a close approach by kestrel that caused a response by another kestrel; **displacement** (DI), a close perching between two kestrels that resulted in pushing of one kestrel by the other; **threat** (TH), an approach by an individual stretching out its neck emphasizing its bill which may be slightly open; **curtsey** (CU), (see Mueller 1971); **physical contact** (PC), a touch by an individual by another with its bill or talon; **bill-bill interaction** (BB), a reciprocal contact with the bills; **allopreening** (AL), a rubbing of the bill of one kestrel against the feathers or talons of another kestrel; **aggression** (AG), a strike by an opponent bird with the bill or talon; **crouching** (CR), a posture in which an individual remains crouched on the ground or on the perch keeping the wings slightly detached from the body, at times in contact with another individual; and **piracy** (PI), a kestrel steals food from another kestrel.

RESULTS AND DISCUSSION

During the first wk after leaving the nest, fledglings stayed on the floor of the aviary, frequently trying to take flight and to climb up the sides. They often landed on other siblings. Fledglings succeeded in reaching perches in the aviary at the beginning of the second wk post-fledging. During the first wk, they roosted on wooden planks at the bottom of the side walls and on a plank found in the center of the aviary.

A total of 962 interactions among fledglings was observed (271 in FG1, 406 in FG2, and 285 in FG3). In all family groups, AL was observed most frequently (Table 1) and sometimes performed in a very exaggerated form as observed by Trollope (1971) and Csermely and Agostini (1993). Curtseying as described by Mueller (1971) was observed only once when a female in FG1 performed this display toward the young male crouched on the floor of the aviary.

Males performed several displays significantly more often than the females: AG ($\chi^2 = 12.56$, $P < 0.01$), DI ($\chi^2 = 8.58$, $P < 0.01$), BB ($\chi^2 = 17.82$, $P < 0.01$), and PC ($\chi^2 = 5.22$, $P < 0.05$). Females, on the other hand, crouched more often ($\chi^2 = 5.68$, $P < 0.05$). Besides displaying AG more frequently than the females, males were also subjected to that behavior more often than expected ($\chi^2 = 8.90$, $P < 0.01$). Aggression between females was observed only 15 times and young males appeared to be more aggressive toward other males. However, aggression never resulted in injury and the attacked bird escaped in 9 cases. Greater aggression by young males might be related to different sex roles of males and females later in life. Adult males are very active in defending nest areas from intruding males. Conversely, females engage in little defense (Palmer 1988).

Fledgling American kestrels seem to be suited to living in groups during the post-fledging period, even in captivity. Allopreening may have had an important role in controlling agonistic behavior, since it may help to keep aggression levels low in family groups. It may ensure that,

Table 1. Frequency of allopreening (AL), threatening (TH), aggression (AG), displacement (DI), bill-bill interaction (BB), physical contact (PC), piracy (PI), crouching (CR), approach (AP), and curtsey (CU) behaviors in three captive American kestrel families (FG1, FG2 and FG3).

FAMILY GROUP	BEHAVIORS									
	AL	TH	AG	DI	BB	PC	PI	CR	AP	CU
FG1	129	18	26	8	34	9	3	25	18	1
FG2	135	34	67	45	80	14	3	3	25	0
FG3	102	20	22	17	68	26	1	18	11	0

when aggression occurs, serious injuries do not occur (Trollope 1971, Harrison 1965, Forsman and Wight 1979, Csermely and Agostini 1993).

Other behaviors may serve other social functions. Bill to bill interactions may facilitate trials of strength or serve as a means of individual recognition as has been suggested for captive common barn-owls (*Tyto alba*) (Csermely and Agostini 1993). Crouching may also be used for individual recognition but it seems more likely to be a posture of submission. This display was shown more frequently by females that rarely showed aggression toward other females. In free living birds, displays of this sort that control aggression among fledglings might encourage the persistence of the family nucleus in the nest area and enhance the formation of juvenile flocks (Cade 1955).

RESUMEN.—Aunque los adultos de la especie *Falco sparverius* muestran agresividad para conespecíficos, los juveniles son extremadamente sociales. Este estudio entrega información sobre la conducta social de volantones cautivos en el núcleo familiar durante el período de dependencia post-volanteo. Nuestras observaciones sugieren que *F. sparverius* le "agrada" vivir en grupo, aunque en un claro contexto no natural, donde ellos controlan sus conductas agonísticas. Los machos juveniles son más agresivos que las hembras juveniles, una conducta que puede estar relacionada con diferentes roles sexuales en su vida posterior.

[Traducción de Ivan Lazo]

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Raptors Feeding on Migration at Eilat, Israel: Opportunistic Behavior or Migratory Strategy?

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Key Words: *feeding; migration; Eilat; opportunistic behavior.*

Many raptors migrate long distances. Palearctic migrants often winter in Africa either by using temporary food sources or by filling niches vacated when local residents move farther south (Newton 1979). En route to wintering grounds, feeding strategies for migrants range from complete fasting (Safriel 1968, Moreau 1972, Mead 1983) to daily foraging (Cochran 1975). Here, I report raptors drinking and eating prey while on migration through Eilat, Israel.

Methods

Reports of feeding or hunting raptors were collected for autumn 1993–95 and spring 1994–95 migrations. Observations were made by the staff of the International Birding Center in Eilat and by many casual bird-watchers. Observations were divided into four major categories: (1) raptors observed drinking water, (2) raptors feeding on roadkills along highways, (3) raptors hunting other birds, and (4) raptors fishing along the beach.

Results

Hundreds of honey buzzards (*Pernis apivorus*) and dozens of black kites (*Milvus migrans*) were regularly seen drinking water with a salinity equal to or greater than that of seawater (Table 1). In contrast, short-toed eagles (*Circaetus gallicus*) and lesser-spotted eagles (*Aquila pomarina*) drank only from a sewage canal where effluents of lower salinity flowed to the Red Sea. All four species were observed drinking water only in the spring probably because they migrate farther north or east of Eilat in autumn and only concentrate at Eilat in spring (Yom-Tov 1984, Shirihai and Christie 1992, Bruderer et al. 1994, Yosef 1995). Black kites have previously been observed to hunt arthropods on the wing while migrating through the rift valley (Bahat 1985) and to drink water while migrating through the Algerian Sahara desert (Dupuy 1969). Honey buzzards appear to be particularly dependent on water and drink salty or brackish water along the migratory route which follows the Red Sea (Shirihai and Christie 1992).

Egyptian vultures (*Neophron percnopterus*) were observed feeding either at the municipal landfill or on carcasses at roadkills (Table 1). On three occasions, they were observed interacting aggressively with brown-necked ravens (*Corvus ruficollis*). Two steppe eagles (*A. nipalensis*) were seen feeding on a road kill. Steppe eagles have been observed feeding on carcasses or to come down and investigate the presence of conspecifics on the ground (W.S. Clark pers. comm.).

Harriers (*Circus* spp.) hunted mostly in the dense corridor of reeds (*Phragmites australis*) along a sewage canal No difference or pattern in their hunting strategy was apparent except for the fact that all prey identified were small birds. Most numerous observations were of marsh harriers (*C. aeruginosus*), which is the most common migrating harrier at the site (Yosef 1995).

Similar to harriers, all observations of sparrowhawks (*Accipiter* spp.) hunting involved avian prey. There are very few reports of Eurasian sparrowhawks (*A. nisus*) migrating at the site, although they are observed in town and in the gardens of hotels. Their hunting activities are seldom observed because they hunt and feed in the undergrowth. Accurate estimates of the number of sparrowhawks that migrate through the region have not yet been obtained because the major migration surveys are done in the mountains and not in the rift valley (Shirihai and Christie 1992, Yosef 1995). Northern goshawks (*A. gentilis*), on the other hand, hunt in open areas such as the salt pans in the Eilat region and are easily observed. Levant sparrowhawks (*A. brevipes*) have a brief migration period in spring. The majority of the hunting observations for this species have been of individuals arriving before or after a large wave of migrants, and their prey almost invariably has been doves. Perhaps this is due to the fact that they are nocturnal migrants and feed during the day (Stark and Liechti 1993).

Steppe buzzards (*Buteo buteo vulpinus*) regularly hunt among date palms and along edges of the agricultural fields (Gorney and Yom-Tov 1994), apparently feeding on arthropods and occasionally on rodents. Clark and Gorney (1987) have observed buzzards drinking, but they were not observed to do so in this study.

Golden eagles (*Aquila chrysaetos*) and Bonelli's eagles (*Hieraaetus fasciatus*) hunted in the mountains only and preyed mostly upon larger animals (Table 1). Similar behavior was observed in a booted eagle (*H. pennatus*) in November 1995, but an individual was also seen to catch an Indian house crow (*Corvus splendens*) when they mobbed the eagle in the date palms. An immature imperial eagle (*A. heliaca*) also captured a chukar (*Alectoris chukar*) on the ground in an agricultural field 10 km north of Eilat.

Numerous falcons were seen foraging while on migration; however, it was difficult to determine the prey spe-

Table 1. Raptors observed feeding while on migration through Eilat, Israel. Habitats are numbered as follows: (1) date plantations, (2) other agricultural crop, (3) salt pans, (4) sewage canal, (5) mountain terrain, (6) city of Eilat, (7) seashore, (8) landfill and (9) highways.

RAPTOR SPECIES	PREY SPECIES	SEASON	HABITAT
Egyptian vulture	Refuse, roadkills	Apr, May	8, 9
Montagu's harrier	Bulbul (*Pycnonotus xanthopygos*)	Apr	2
Pallid harrier	Bulbul	Sept	4
	House sparrow (*Passer domesticus*)	Apr	6
Marsh harrier	Spur-winged plover (*Hoplopterus spinosus*)	Sept	3
	Little stint (*Calidris minuta*)	Oct, June	3
	Reed Warbler (*Acrocephalus* sp.)	Mar	4
	Phylloscopus sp.	June	4
	Graceful Warbler (*Prinia gracilis*)	Apr	4
Eurasian sparrowhawk	Sparrow (*Passer* sp.)	Mar, June	6
	Blackcap (*Sylvia atricapilla*)	4 – 94	
Northern goshawk	Black-winged stilt (*Himantopus himantopus*)	Dec	3
	Quail (*Coturnix coturnix*)	June	6
	Pigeon (*Columba livia*)	Oct, Nov, Dec	2, 6
	Collared dove (*Streptopelia decaocto*)	Nov	3
Levant sparrowhawk	Turtle dove (*Streptopelia turtur*)	Apr	1
	Laughing dove (*S. senegalensis*)	Apr	1
	Namaqua dove (*Oena capensis*)	May	3
Steppe buzzard	Unidentified rodent Arthropods	Apr, May, June	1, 2
Golden eagle	Egyptian dab lizard (*Uromastix aegyptius*)	May June	5
	Syrian Hyrax (*Procavia capensis*)	Apr	5
	Brown hare (*Lepus capensis*)	Apr	5
Imperial eagle	Chukar (*Alectoris chukar*)	Oct	2
Steppe eagle	Roadkills	Mar	9
Bonelli's eagle	Sand Partridge (*Ammoperdix heyi*)	Apr	5
Booted eagle	House crow (*Corvus splendens*)	Mar	1
	Brown hare	Nov	5
Osprey	Fish	Mar, Apr	7
Red-footed falcon	Arthropods	Apr	2

Table 1. Continued.

RAPTOR SPECIES	PREY SPECIES	SEASON	HABITAT
Eurasian kestrel	Unidentified rodent	Oct	2
Lesser kestrel	Arthropods	Mar, Apr	2
Peregrine falcon	Redshank (*Tringa totanus*)	Apr	3
Lanner falcon	Little stint	Sept, Oct	3

cies taken owing to the small size and the distance at which they were observed. Their preferred hunting habitat was either open agricultural fields or salt pans where they hunted arthropods or rodents in the former, and waders in the latter.

Ospreys (*Pandion haliaetus*) caught and fed on fish from aquaculture ponds which are used to raise *Oreochromis mozambicus* and *Tilapia mozambicus*. Ospreys have previously been reported to feed while on migration (Kerlinger 1989). Shirihai and Christie (1992) considered ospreys rare migrants at Eilat in autumn. However, all observations were in spring suggesting that the few passing through in autumn do not usually stop at Eilat. During spring, it appears that the majority of osprey continue their migration north through the Eilat mountains (Yosef 1995) and not along the coast. These individuals may be in better body condition than those observed foraging along the shores of Eilat. This is consistent with Candler and Kennedy's (1995) suggestion that the "jump" strategy (foraging at several mid-migration stopovers) is the best strategy for migrating ospreys.

In conclusion, over a period of five migratory seasons, individuals of 23 of the 33 raptor species that migrate through Eilat (Yosef 1995) were observed drinking or hunting. The fact that relatively low numbers were seen to either feed or drink suggested that it was only hungry (Gorney and Yom-Tov 1994) or opportunistic raptors that fed in Eilat. The fact that no species were observed to stop at Eilat *en masse* indicated that the majority of individuals fasted while migrating through the region. Those individuals observed in the area used date palms, agricultural fields and/or mountains around Eilat as roosting sites. During the spring migration, raptors in the eastern Palearctic flyway may attempt to get to their breeding grounds as fast as possible and are probably time minimizers.

RESUMEN.—En cinco estaciones migratorias, individuos de 23 de las 33 especies de rapaces que migran a través de Eilat, Israel, fueron observados bebiendo o cazando. *Pernis apivorus, Milvus migrans, Circaetus gallicus* y *Aquila pomarina*, bebieron agua durante su pasaje sobre el área; *Neophron percnopterus* y *A. nipalensis* fueron observados comiendo en diversos terrenos. *Buteo buteo vulpinus, A.*

chrysaetos, Hieraaetus fasciatus, H. pennatus, A. heliaca, Circus spp. y *Accipiter* spp. cazaban mayormente presas vertebradas; *Pandion haliaetus* cogía peces en estanques de aquacultura.

[Traducción de Ivan Lazo]

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LETTERS

OBSERVATIONS OF KING VULTURES (*SARCORAMPHUS PAPA*) DRINKING AND BATHING

Despite the extensive geographic range of the king vulture (*Sarcoramphus papa*) from central Mexico to northern Argentina, little is known about its life history (L. Brown and D. Amadon 1968, Eagles, hawks, and falcons of the world. McGraw-Hill, New York, NY U.S.A.; J. del Hoyo, A. Elliot and J. Sargahal 1994, Handbook of the birds of the world, Vol. 2, New world vultures to guineafowl. Lynx Edicions, Barcelona, Spain). During the dry season from March through June 1993–95, we observed king vultures opportunistically during a study of the orange-breasted falcon (*Falco deiroleucus*) in Belize and Guatemala. We observed king vultures drinking and bathing from a series of large, clear pools above a 300 m waterfall (ca. 1000 m amsl) in the Mountain Pine Ridge area of the Maya Mountains, Cayo District, Belize. Topographic relief is extreme, with ridgetops and high plateaus dominated by Caribbean Pine (*Pinus caribaea*) and tropical semi-deciduous forest occurring in valleys and lowlands. The creek-fed pools used by the vultures were eroded into the granitic bed rock, free of vegetation for more than 10 m on either side, and completely open downstream where the water plunged over a precipitous valley edge. King vultures were observed at this site at all times of day throughout our observation period. They were seen perched in trees or on the ground at pools, sunning in a spread-wing posture, preening, drinking and bathing. At times, they soared on the strong updrafts above the area.

On 19 March 1993, we saw 12 individuals (9 adults and 3 subadults) above the waterfall. Seven adults and one subadult periodically drank while the remaining four bathed vigorously. All these vultures had visibly distended crops indicating they had recently fed. On 18 May 1994, we observed similar behavior by five adults; four were drinking and one was bathing, but none had visibly distended crops. On 31 March 1995, four vultures were perched above the waterfall, four soared nearby, and three perched in trees within 500 m of the falls. Of the four above the waterfall, two were adults and two were subadults; all four were observed drinking and one adult and one subadult were also seen bathing. Of these four vultures, only the nonbathing subadult had a visibly distended crop.

Houston (1984, *Ibis* 126:67–69; 1988, *Ibis* 130:402–417) has shown that king vultures probably do not locate food by smell but follow vultures of the genus *Cathartes* to carcasses. Lemon (1991, *Wilson Bull.* 103:698–702), in contrast, found that king vultures sometimes arrived first at carcasses in forests, and speculated that nonvisual cues, possibly including olfaction, were used to locate carrion. If king vultures depend in part on the olfactory ability of *Cathartes* in finding food, then they may have to feed largely on desiccated carrion, especially in areas with pronounced dry seasons, necessitating drinking to maintain adequate water balance.

Koford (1953, The California Condor. National Audubon Society, New York, NY U.S.A.) described frequent drinking and bathing by California condors (*Gymnogyps californianus*). He suggested that California condors prefer clean pools above waterfalls (similar to those where we observed king vultures) but noted that they will drink from a variety of sources including stagnant pools in potholes when necessary. Similarly, McGahan (1972, Behavior and ecology of the Andean Condor. Ph.D. dissertation, University of Wisconsin, Madison, WI U.S.A.) observed Andean condors (*Vultur gryphus*) drinking and bathing in pools on cliff ledges. Koford concluded that drinking by California condors, though irregular in occurrence, is necessary, and emphasized that ". . . the protection of frequented watering places from disturbance is highly essential to the welfare of condors."

To our knowledge there are no previously published observations of drinking or bathing by wild king vultures It remains uncertain whether king vultures depend on drinking to maintain water balance. While many carnivorous birds can live for months without drinking, this hinges on the thermal environment and preformed water content of the diet (Bartholomew and Cade 1963, *Auk* 80:504–539). M. Schlee (pers. comm.) suggests that captive cathartids drink more in general than do old world vultures, and attributes this to use of urohidrosis by the former. If king vultures need to drink and/or bathe regularly, then the distribution of suitable drinking and bathing sites could be an important determinant of habitat quality and hence of the distribution and population density of this species.

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OBSERVATIONS OF A PAIR OF NESTING COOPER'S HAWKS IN SAN FRANCISCO, CALIFORNIA

Increasing attention has been focused on raptor species that nest in urban environments (L. Oliphant and E. Haug 1985, *J. Raptor Research* 19:56–59; P. Bloom et al. 1993, *J. Wildl. Manage.* 57:258–265; C.M. White 1994, *Studies in Avian Biology* 15:161–172; R.N. Rosenfield et al. 1995, *J. Raptor Research* 29:1–4). In this letter, we report observations of nesting Cooper's hawks (*Accipiter cooperii*) in San Francisco, California. To our knowledge, this is the first nest record for the species in the city and county of San Francisco, California.

The breeding territory was located in the Fort Funston National Recreation Area, located on the immediate Pacific coast in the southwestern region of San Francisco. This area is a unit within the Golden Gate National Recreation Area and is administered by the U.S. Park Service, Department of Interior. Vegetation in the area consists primarily of exotic species, occurring as patchy stands of eucalyptus (*Eucalyptus spp.*) or Monterey cypress (*Cupressus macrocarpa*) interspersed with open sand dunes dominated by sea fig (*Carpobrotus aequilaterus*). Several paved paths dissect the area, which receives extensive human use primarily in the form of dog walkers, hikers and tourists. Literally scores of unleashed dogs and walkers inundated the immediate nest area daily.

Adult Cooper's hawks were sporadically observed in this area from May–July 1994. During September 1994 a stick nest was observed in a eucalyptus tree approximately 8 m from a heavily-used paved path. Prey remains, whitewash and molted Cooper's hawk feathers at the base of the nest tree and fresh down present around the rim of the nest suggested a pair of Cooper's hawks attempted to nest during the 1994 breeding season. The nest was located 9.4 m above the ground in a 41 cm diameter at breast height eucalyptus tree. The nest tree was located in a mixed stand of eucalyptus and cypress that was approximately 200 m long and 50 m wide.

On 24 March 1995, Cooper's hawks were first observed in the area when an adult male was seen pursuing flocks of Brewer's blackbirds (*Euphagus cyanocephalus*) and rock doves (*Columba livia*) over a paved parking lot located approximately 300 m south of the 1994 nest stand. A second-yr female carrying a stick flew into the nest stand. A stick nest was observed in a eucalyptus tree approximately 90 m south of the 1994 nest tree. The nest tree was located within a few meters of both a popular picnic table and a heavily-used path. On 4 April, the female was observed incubating in this nest. On the morning of 23 April, neither the female nor male was found in the nest stand area, the nest had fallen out of the tree and several egg shell fragments were located at the base of the tree. Although we could not determine the cause of the nest failure, we suspect that the nest may have blown out of the tree. The nest appeared to be poorly constructed and was situated on a bluff along the immediate coast overlooking the Pacific Ocean, an area regularly buffeted by strong onshore winds.

On 27 April, the pair was observed in the immediate vicinity of the 1994 nest site. A copulation was observed at this nest site on 29 April following a prey delivery by the male. On 7 May, the female was observed feeding at a plucking post and the male was perched on the rim of the nest. Another copulation was observed on 9 May following another prey delivery. Egg laying and incubation were estimated to have been initiated on 9–11 May. Hatching was estimated to have occurred on 12–15 June. On 17 June, the female was observed feeding nestlings and on 24 August, a single fledgling was seen perched near the nest. The fledgling apparently dispersed soon after this date and was not observed on subsequent visits.

Limited observations of prey deliveries and prey remains resulted in identification of six prey species: five birds, Brewer's blackbird, rock dove, mourning dove (*Zenaida macroura*), scrub jay (*Aphelocoma coerulescens*), American robin (*Turdus migratorius*), and one mammal (an unknown sciurid).

Our observations showed that this pair of Cooper's hawks was able to exploit a breeding territory with a high degree of human activity. Limited food observations indicated that these hawks preyed on both introduced and native species that are common within the urban environment of San Francisco. Further, they were able to use an introduced nonnative tree species for nesting. Eucalyptus trees are widely distributed throughout western California in both urban and natural environments and are commonly used by raptors such as red-shouldered hawks (*Buteo lineatus*),

red-tailed hawks (*B. jamaicensis*), and great horned owls (*Bubo virginianus*). Great horned owls also nest in eucalyptus trees within the city of San Francisco (J.J. Keane pers. observ.).

This is the first confirmed nest record for Cooper's hawk in San Francisco, California. Observations of Cooper's hawks during the breeding season in other parts of San Francisco, particularly Golden Gate Park and the Presidio (Golden Gate National Recreation Area), suggest the presence of additional nesting pairs in the city. Given the widespread habitat modifications associated with a population growth rate of approximately 600,000 people per year in California (T. Palmer 1993, California's threatened environment, Island Press, Covelo, CA U.S.A.), further study of these Cooper's hawks could provide valuable information related to Cooper's hawk management and conservation.—**Nadia Sureda, RR3 Box 17A, Vermillion, SD 57069 U.S.A. and John J. Keane, Department of Avian Sciences, University of California, Davis, CA 95616 U.S.A.** Present address for Keane: Stanislaus National Forest, 19777 Greenley Road, Sonora, CA 95370 U.S.A.

PRESENCE OF BREEDING NORTHERN GOSHAWKS IN THE COAST RANGE OF OREGON

Northern goshawks (*Accipiter gentilis*) nests have been found in all forested areas of Oregon except the Coast Ranges of the western portion of the state (R.T. Reynolds et al. 1982, *J. Wildl. Manage.* 46:124–138, T. Schommer and G. Silovsky 1994, USDA For. Ser. Status Rep. Pac. Northwest Reg. Off., Portland, OR U.S.A., and S. DeStefano et al. 1994, *Studies Avian Biol.* 16:88–91). Although goshawks have been observed in the Coast Ranges during the breeding season and at other times of the year (S. DeStefano unpubl. data), breeding activity has never been observed there.

On 7 and 20 June 1995, we observed two occupied northern goshawk nests in the Coast Ranges of Oregon (44°11′N, 123°36′W and 44°16′N, 123°26′W). A straight-line distance between the two nests was 16.1 km. The nests were discovered during surveys for northern spotted owls (*Strix occidentalis caurina*) in the Eugene Bureau of Land Management District, Oregon. Vegetation in this area is dominated by forests of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*).

Adult goshawks responded with "alarm calls" to our imitations of spotted owl calls during daytime surveys. We then played recorded goshawk calls to find the goshawks and their nests. Each goshawk nest was located within 150 m of an historic owl nest tree/activity area. We observed three young at the first nest and two young at the second. We estimated the first brood to be 9–12 d and the second brood at >40 d of age (C.W. Boal 1994, *Studies Avian Biol.* 16:32–40). Two of the three nestlings in the first brood eventually died of unknown causes. The first mortality occurred at 16–19 d of age and the second occurred when the nestling was 35 d old.

The dbh (diameter at breast height) of both Douglas-fir nest trees were smaller (33.5 and 33.0 cm) than those used by goshawks in other areas of Oregon (T. Schommer and G. Silovsky 1994, USDA For. Ser. Status Rep. Pac. Northwest Reg. Off., Portland, OR U.S.A.). One nest tree was alive and the other was a Class I snag (dead, but retaining its branches) (C.R. Maser et al. 1979, pages 78–93 *in* J.W. Thomas, Ed., USDA For. Ser. Agric. Handbook 553). However, nest height (8.1 and 20.9 m) was similar to nests located in other areas of Oregon (T. Schommer and G. Silovsky 1994, USDA For. Ser. Status Rep. Pac. Northwest Reg. Off., Portland, OR U.S.A.). Nests were constructed of sticks, lichens, moss and Douglas-fir needles, but were different shapes. The first nest was "cuplike" whereas the second nest was more "platform" in shape. The weathered appearance of both nests suggested that they were >1 year old. We located an alternate nest structure in the nest stand of the second nest, suggesting that the territory may not be ephemeral (B. Woodbridge and P.J. Detrich 1994, *Studies Avian Biol.* 16:83–87).

Nest stands were similar in both size (11 and 16 ha) and structure. Forest fires and selective timber harvest occurred in the nest stands 50–60 yr ago, accounting for the smaller trees (28–52.9 cm dbh) in the stands and a component of large overstory trees (53+ cm dbh) in the stands. These "young" stands also contained an open understory, residual components of down woody debris and snags.

The Coast Ranges of Oregon appear to have all of the structural types of habitat with which breeding goshawks are associated (R.T. Reynolds et al. 1982, *J. Wildl. Manage.* 46:124–138). Despite a decade of annual surveys for spotted owls and other forest breeding birds, the relative absence of breeding goshawks in the Coast Ranges is well-documented. It is not clear why goshawks breed at such low densities in the Coast Ranges when compared to other areas of the Pacific Northwest.

PREDATION ON A BALD EAGLE NESTLING BY A RED-TAILED HAWK

No incidents where a raptor has taken a bald eagle (*Haliaeetus leucocephalus*) nestling from a nest while the adult eagle was present have been reported. We observed an adult red-tailed hawk (*Buteo jamaicensis*) remove a bald eagle nestling from a nest on Santa Catalina Island, California on 2 April 1996. The incident occurred while we were monitoring the eagle nest from about 300 m through a spotting scope as part of a study of nesting behavior in a reintroduced population of bald eagles impacted by DDE contamination.

Since 1989, bald eagle nests on Santa Catalina Island have had eggs with high DDE levels replaced with artificial eggs, and later healthy chicks have been reintroduced back into the nests. On 30 March 1996, we fostered 9- and 11-day-old nestlings into the nest where the predation occurred. On 2 April, the female eagle was observed on the nest in brooding posture. One of the introduced nestlings was obscured from view, probably sheltered by the female, while the other nestling was lying in front, approximately 25 cm away from the mother eagle. At 1018 H, a mature red-tailed hawk flew in and grabbed the nestling in front of the female. As the hawk took the nestling, the adult eagle vocalized and flapped its wings. Immediately, the female eagle flew from the nest chasing after the hawk. Less than a minute later, the female eagle returned to the nest with the nestling in its talons, placed it on the edge of the nest, and began brooding the other nestling that had been left unattended. The nestling removed by the red-tailed hawk did not move after it was returned, presumably killed either by the hawk or during its recovery by the eagle.

At 1022 H, the red-tailed hawk again tried to take the dead nestling, but it was unsuccessful. The male eagle was not seen in the vicinity of the nest until 1057 H, when it flew within 100 m of the nest over ½ h later. From 1103–1111 H, the female eagle fed the dead nestling to its nest mate and consumed part of the carcass herself.

We have monitored incubation and chick-rearing behavior of adult eagles on Santa Catalina Island at 14 nests since 1989. This is the only instance of predation on a nestling eagle that we have observed. However, in areas that red-tailed hawks and bald eagles commonly cohabitate, predation by red-tailed hawks may be a more frequent cause of mortality for nestling eagles.

We would like to thank the Santa Catalina Island Conservancy for their support and permission to conduct this study on their property. Funding for the project was provided by the Natural Resource Damage Assessment Branch, U.S. Fish and Wildlife Service.—Dustin W. Perkins, Dave M. Phillips and David K. Garcelon, Institute for Wildlife Studies, P.O. Box 1104, Arcata, CA 95518 U.S.A.

BOOK REVIEWS

EDITED BY JEFFREY S. MARKS

Raptors in Human Landscapes: Adaptations to Built and Cultivated Environments. Edited by David M. Bird, Daniel E. Varland and Juan Jose Negro. 1996. Academic Press, London, U.K. xx + 396 pp., numerous figures and tables. ISBN 0-12-100130-X. Cloth, $72.00.—We may like to think of raptors as birds of wild and pristine lands, but in reality, the modern world has relatively few of these places left. Thus, raptors and other species must cope with a world drastically altered by humans. This book shows that certain raptors have been able to do so with some success.

Thirty-four relatively short chapters (mean chapter length is 10 pages) by 73 contributors discuss a variety of problems that raptors face in human-influenced environments around the world. Duration of the studies reported on varies widely from 9 d (Chapter 25) to 25 yr (Chapter 4), and as would be expected, depth of coverage ranges from rather shallow and qualitative to extensive and highly quantitative.

Editing is uniform, and I found few typographical errors and only a split infinitive or two. The editors, oddly though, did not conform to one style in spelling—North American chapters use American spelling but chapters from most other geographic areas use British spelling (e.g., behavior vs. behaviour). Scientific names are listed in the appendix, but the authority followed is not indicated. At least one name was misspelled—*Accipiter cooperi* instead of *cooperii*.

The chapters are divided into five sections that were somewhat arbitrarily established; numerous other arrangements could have been used. Several of the chapters could just as well fit in one or more other sections (e.g., Chapter 17 is in the section "Raptors and Artificial Nest Sites" but could have been put in the section "Raptors in Cultivated Landscapes").

The first section is called "Raptors in Urban Landscapes" and consists of nine chapters that deal mostly with raptors nesting in urban areas. It leads off with three chapters concerning peregrine falcons (*Falco peregrinus*). Chapter 1 by Tom Cade, Mark Martell, Patrick Redig, Gregory Septon and Harrison Tordoff presents rather general information on the numbers of peregrines nesting in North American cities, and gives a qualitative list of prey known to be taken by peregrines in cities. Chapter 2 by Douglas Bell, David Gregoire and Brian Walton discusses the use of bridges in San Francisco for nesting, noting that fledging success was poor and that bridge sites need to be enhanced to improve productivity. Gregory Septon and Jim Marks documented eggshell thinning in Wisconsin urban-nesting peregrines in Chapter 3. Pesticide and PCB contamination were in the middle of the range of other North American studies.

In Chapter 4 Peter Bloom and Michael McCrary claim that the red-shouldered hawk (*Buteo lineatus*) is the buteo most tolerant of human activities—it is adapted to urban environments by its small home range size and its diet of invertebrates and small vertebrates.

Robert Rosenfield, John Bielefeldt, Joelle Affeldt and David Beckmann in Chapter 5 dispel the notion that Cooper's hawks (*Accipiter cooperii*) cannot nest successfully in fragmented forests and suburban areas. On their Wisconsin study area they found the highest nesting densities known for Cooper's hawks, and they discovered that the mean clutch size and number of nestlings were comparable to the highest known elsewhere.

Chapters 6 through 8 show how three disparate raptors have adapted successfully to urban nesting places. James Parker in Chapter 6 maintains that Mississippi kites (*Ictinia mississippiensis*) are well suited to urban landscapes. Lesser kestrels (*Falco naumanni*) nesting in urban Spain, discussed in Chapter 7 by José Tella, Fernando Hiraldo, José Donázar-Sancho and Juan Negro, seemed to benefit from lower predation upon their eggs and nestlings compared with rural areas. On the other hand, they suffered from reduced availability of food in the urban settings. In Chapter 8, Eugene

Botelho and Patricia Arrowood noted that the burrowing owl (*Speotyto cunicularia*), like the lesser kestrel, may have gained the advantage of reduced predation on its young in urban areas, but in contrast to the lesser kestrel may have access to increased food resources compared with rural habitats.

In the final chapter (Chapter 9) of this section, Frederick Gehlbach summarized his long-term studies on eastern screech-owls (*Otus asio*) and proposed a model of raptor response to urban habitats. His model is based on shifts in behavior of raptors in response to the more clement climate and more abundant food resources in urban areas compared with rural or natural areas. Unlike most chapters in the book, this one has no methods section.

The second section of the book, containing eight chapters, is called "Raptors and Artificial Nest Sites." Leading off in Chapter 10, William Stout, Raymond Anderson and Joseph Papp chronicled 15 red-tailed hawk (*Buteo jamaicensis*) nests on high-voltage power transmission towers and billboards in the Milwaukee, Wisconsin metropolitan area. Compared with natural nest sites, those on artificial structures were more successful but not significantly more productive.

Roberta Blue in Chapter 11 shared the results of a mail survey on the use of electric utility facilities by nesting raptors. A 62% response rate (of 141 companies) revealed that 10 diurnal raptor species and two owl species have used these facilities for nesting. No information is given on success rates, but enhancement projects for raptors were noted, mostly the installation of nest structures.

The next three chapters deal with ospreys (*Pandion haliaetus*) and artificial structures, and all three attribute increases in osprey populations to the use of artificial nesting structures. In Oregon, Charles Henny and James Kaiser (Chapter 12) documented a sixfold increase in nesting from 1976–1993. In the Canadian Great Lakes basin, Peter Ewins (Chapter 13) noted that ospreys have used artificial structures since 1945, and that reproductive success is slightly higher on artificial sites. Ospreys in Germany have used high-voltage transmission towers since 1938 (Chapter 14 by Bernd Meyburg, Otto Manowsky, and Christiane Meyburg). Today, >75% of ospreys nest on these towers, where they produce more offspring on average than ospreys nesting in trees.

In Chapter 15, James Tigner, Mayo Call and Mi-

chael Kochert recount the history of artificial nest structures for ferruginous hawks (*Buteo regalis*) in Wyoming. Nesting density did not increase with the addition of the nest structures, but reproductive success was significantly greater for pairs using artificial structures vs. natural substrates.

Gregory Septon, John Bielefeldt, Tim Ellestad, Jim Marks and Robert Rosenfield (Chapter 16) discussed the use of power plant structures for nesting by peregrine falcons in the upper midwestern United States. The most valuable information in this chapter is probably the dispersal movements of peregrines from natal sites to places of nesting.

In Chapter 17, Marc Bechard and Joseph Bechard recorded that American kestrels (*Falco sparverius*) gradually excluded European starlings (*Sturnus vulgaris*) from nest boxes placed in a rural Idaho area. In the last 4 yr of the study, kestrels used 100% of the available boxes.

"Raptors in Cultivated Landscapes" is the third section of the book. It begins with Chapter 18 by Andrea Erichsen, Shawn Smallwood, Marc Commandatore, Barry Wilson and Michael Fry that documents the decline in habitat for white-tailed kites (*Elanus leucurus*) in the Sacramento Valley of California. Only nine of 22 nests they studied produced fledglings, and much of the failure was attributed to displacement by other raptors.

Chapter 19 also occurred in the Sacramento Valley. Shawn Smallwood, Brenda Nakamoto and Shu Geng surveyed raptor use of farmlands, and found that 15 raptor species had definite preferences for landscape characteristics. Bare soil, human settlements and most row crops were avoided, and riparian areas, wetlands, uplands, alfalfa and stubble fields generally were preferred. The authors provide information that may help increase raptor populations in farmlands.

The next two chapters reveal how native deciduous forests, largely eliminated by humans in Britain, have been replaced by conifer plantations and reforestation with coniferous trees. Ian Newton in Chapter 20 showed that Eurasian sparrowhawks (*Accipiter nisus*) prefer to nest in conifer plantations vs. native deciduous forests in Scotland. In Chapter 21, Steve Petty documented that the forested area in Britain has doubled in the last 75 yr, mostly from planting conifer forests on marginal agriculture areas. Fourteen of the 16 raptor species that occur in British uplands have either benefited or have been unaffected by these forest increases. Only the hen harrier (*Circus cyaneus*) and golden eagle (*Aq-*

uila chrysaetos) may be adversely affected because they need open lands for foraging.

Scott Horton (Chapter 22) told how northern spotted owls (*Strix occidentalis*) might make use of managed forests. The conclusions, though, are based on an extensive review of spotted owl habitat characteristics and forest management instead of field studies designed to discover if the owls actually can maintain stable populations in managed forests.

In Chapter 23, Robert Kenward notes that northern goshawks (*Accipiter gentilis*) seem to have adapted well to deforested areas in Europe but not so in North America. He proposed three hypotheses for this difference, preferring the one that attributes the reduced success in North America to lower winter food availability and competition from *Buteo* species and great horned owls (*Bubo virginianus*).

Chapters 24 and 25 deal with problems rainforest raptors have with human alterations of their habitat, but the two studies differ considerably in scale. The one reported in Chapter 24 by Jean-Marc Thiollay was conducted in Sumatra to assess raptor responses to cultivated forests in comparison with primary forests and open cultivated lands. He concluded that agroforests serve as adequate habitat for only one-quarter of the primary forest raptor community. Agroforests were better, though, than the open cultivated lands. In Chapter 25, Eduardo Alvarez, David Ellis, Dwight Smith and Charles Larue worked in rainforest in Venezuela that also has faced extensive human changes. Their roadside survey was conducted in just 9 d, in which time they recorded 42 raptor species.

In the final Chapter (26) in this section, Nick Mooney and Robert Taylor discussed problems that wedge-tailed eagles (*Aquila audax*) in Tasmania face from logging. Lowered reproductive rates are usually the result of such disturbance, and retaining buffer zones around nests is not sufficient because the species needs large areas of undisturbed forests for foraging.

The initial image brought forth by the title of the fourth section, "Raptors in Industrial Landscapes" was not borne out by the four chapters therein. I had visions of heavy manufacturing, refineries and the like, but the "industrial" landscapes were impoundments, reclaimed strip mines and airports. Chapters 27 and 28 relate the use of artificial lakes by bald eagles (*Haliaeetus leucocephalus*) in the southeastern United States. Law-

rence Bryan, Thomas Murphy, Keith Bildstein, Lehr Brisbin and John Mayer (Chapter 27) documented the rapid increase in nesting and high rate of success for bald eagles using reservoirs in South Carolina. Richard Brown (Chapter 28) found that wintering bald eagles were attracted to areas below dams in North and South Carolina. He believed that the attraction was due to good food resources and presence of large, mature trees for perching.

Grasses and forbs used in the reclamation of strip mines in Pennsylvania produce nonforested areas important for the nesting of northern harriers. Ronald Rohrbaugh and Richard Yahner in Chapter 29 showed that harriers were commonly associated with such reclaimed strip mines, but lacked data to document the extent of nesting.

S.M. Satheesan's 14-yr study of 30 airports in India found that 33 raptor species, most commonly vultures and kites, were attracted to airports. Sources of food and places to roost and nest seem to be what attracted the raptors. These concentrations of raptors at airports produced 552 incidents of aircraft/raptor collisions resulting in high economic losses.

The final section called "Raptors at Large" contains four chapters that the editors apparently could not decide where to place elsewhere. They have no relationship to each other except, like each case documented in this book, they are examples of raptors coping with human-dominated landscapes.

David Houston in Chapter 31 noted that living in human-dominated landscapes can have both advantages and disadvantages for vultures. Some species have benefited by increased food supplies from domestic livestock. Others have suffered from shooting, poisoning (often as nontarget species) and electrocution on electrical transmission lines. Ron Hartley, Kit Hustler and Peter Mundy (Chapter 32) reviewed the overall impact of humans on raptors in Zimbabwe. Zimbabwe is a small country with a high diversity of raptors and a high human population growth. Nearly half of the raptor species have been negatively affected by habitat destruction, but about one-quarter of the species may benefit from some human changes in the landscape.

Two raptor species have benefited from human activities in Mexico. Ricardo Rodríquez-Estrella (Chapter 33) showed that common black-hawks (*Buteogallus anthracinus*) were much more abundant in one vicinity, apparently the result of in-

creased riparian habitat created by damming a river. Increased food supplies seemingly have contributed to increased populations of crested caracaras (*Caracara plancus*). Caracaras used a variety of foods from human sources including slaughterhouse remains, dead domestic livestock and garbage dumps. A general overview of how raptors are faring in Mexico, which is not given, would have helped to evaluate these two cases.

The last chapter in the book describes the Rocky Mountain Arsenal near Denver, Colorado, recently designated as a national wildlife refuge, as a habitat oasis for raptors within a dense human population. Despite heavy chemical contamination and considerable human activity, raptor densities there are high. Charles Preston and Ronald Beane concluded from their studies on the arsenal that raptors may be able to adapt to human activity if given adequate foraging, roosting and nesting areas.

This book will be a valuable resource for wildlife managers that must deal with problems facing raptors. It shows how some species, at least, can cope with what we humans are doing to the world. Most of the human-caused problems in the book arise from habitat changes, and little coverage is given to other significant problems like chemical contamination. It would have been helpful, for balance, to include additional material on species that have not coped as well in human-dominated landscapes, lest we think that all is rosy. All in all, this book is a valuable resource and one that libraries and raptor enthusiasts will want to include in their collections.—**Carl D. Marti, Department of Zoology, Weber State University, Ogden, UT 84408 U.S.A.**

Raptors: The Birds of Prey. By Scott Weidensaul. 1996. Lyons and Burford, New York, NY. ix + 382 pp., 5 figures, 121 tables, 25 maps, 153 color photos, 9 black-and-white photos. ISBN 1-55821-275-2. Cloth, $40.00.—Scott Weidensaul, nature columnist for the *Philadelphia Inquirer* and outdoor editor for the *Harrisburg Patriot-News*, is already the author of more than two dozen natural history books. He

has chosen his publisher well—Lyons and Burford are building a reputation for high-quality nature books, as exemplified by Bill Burt's recent *Shadowbirds.*

Weidensaul admits up front that his title is misleading—his book deals only with diurnal raptors and hence omits owls. *Raptors* is sumptuous, comprehensive, well-organized, well-written and packed with information, much of it succinctly presented in 121 tables. The book contains 153 high-quality color photographs and another nine in black-and-white. This is truly a beautiful book.

Weidensaul is careful to credit the literature for almost all information provided in the tables and maps, but most statements in the text are not acknowledged as to source. I found this annoying in places, as with his bold, unsubstantiated statement that the peregrine falcon (*Falco peregrinus*) is "the most successful wild bird in existence." Who said so, and when? Might others not measure success in terms of reproductive productivity rather than by the speed of the attack, or percentage success in stoops?

When any book attempts to be all-inclusive, one looks for topics insufficiently emphasized. In this book, the defect is in reproduction/productivity. I would have liked to have seen Weidensaul quote and expand on Ian Newton's statement: "almost every aspect of the natural population of a given raptor species can be explained in terms of food." While Weidensaul reports the changing food habits of the northern harrier (*Circus cyaneus*) as coincident with the cyclic numbers of voles, he fails to make the point that annual productivity (young per pair or per successful nest) may swing widely from year to year. Nor does he mention the great individual variation in reproduction, such as Ian Newton's demonstration that 7% of Eurasian sparrowhawk (*Accipiter nisus*) fledglings, 30% of the breeders, produce 90% of the subsequent young (Newton, *Lifetime Reproduction in Birds,* 1989:179-296).

The terms Malagasy and Madagascar are used inconsistently, without explanation. Dragonflies should be added as a prey item of the Swainson's hawk (*Buteo swainsoni*) in Argentina. The "kee-kee-kee" vocalization of the merlin (*Falco columbarius*) is omitted from the table of typical calls. Recent use of DNA fingerprinting in avian paternity studies is not mentioned. The table listing characteristic additions to raptor nests fails to mention the almost universal presence of cowdung in ferrugi-

nous hawk (*Buteo regalis*) nests. The statement that a raptor will "sometimes" tolerate humans climbing into the nest to band the young is remarkably negative, coming from a bander. Conversely, the remarkable predilection of some buteos, but especially Swainson's hawks, to desert their nest and not renest that season after a climber views the eggs, is not given sufficient emphasis. Also misleading is the statement that in nesting areas, the Swainson's hawk "feeds heavily on insects." This is abundantly true when they flock and prepare for southward migration, but under normal circumstances the nestlings in Saskatchewan are fed almost exclusively on ground squirrels. Fostering into wild nests as a placement for healthy nestlings (e.g., after a nest is inadvertently bulldozed), is not mentioned.

Indexing is not ideal, with "northern harrier" and "northern goshawk" indexed under N, not H and G, and with no indexing of the use of crow and magpie nests by merlins. The list of raptor organizations is inevitably incomplete. I found only one typographical error apart from consistent misspelling of Steller's sea-eagle as "Stellar's." One glitch on p. 202 mentions the "following" list, which by printing time became the preceding list!

This book, minor shortcomings aside, serves as a comprehensive introduction to almost all aspects relating to diurnal raptors, from biblical references to the economics of hawkwatching (average expenditure of $1,850 per hawkwatcher per year). Keith Bildstein's dust-cover evaluation states that "Weidensaul provides novices and raptor aficionados alike with engaging yet thorough, up-to-date reviews of raptor taxonomy, natural history, ecology, and conservation. The best and most complete popular treatment of this charismatic group in years." I concur, but I would recommend it especially for the novice.—**C. Stuart Houston, 863 University Drive, Saskatoon, SK S7N 0J8 Canada.**

Australian Birds of Prey: The Biology and Ecology of Raptors. By Penny Olsen. 1996. Johns Hopkins University Press, Baltimore, MD. 256 pp., 37 tables, numerous figures and color photographs. ISBN 0-8018-5357-5. Cloth, $49.95.—Considering the wealth of information contained in this book, the array and quality of the photographs and the price, the book is a steal even for those not interested in birds of prey. To better appreciate the value of the informational content of this book, one must first have some brief knowledge of the author's background. Dr. Olsen has done extensive work, among other things, on the ecology of native Australian rodents but received her degree while working with Professor Andrew Cockburn, Australian National University, of *An Introduction to Evolutionary Ecology* text fame. Her dissertation (1991) was entitled *Aspects of the Evolutionary Ecology of Reproduction of Raptors.* The dissertation contained 11 chapters on topics as varied as "Avian Egg Morphometrics," "Female-biased Sex Allocation," "Pesticide-related Eggshell Thinning," and "Do Large Males Have Small Testes?" My personal feeling is that her dissertation gave her much of the foundation to launch forth with the present book. She has a wealth of both intensive and extensive background and field work to do a superb job on such a book. *Australian Birds of Prey* is of large format, some 32 by 25 cm in size; a good coffee table book although of a decidedly more scientific genre. The book is divided into nine chapters, and the format departs somewhat from the traditional outline of such books. Following the Introduction, chapters are "Australia's Species" (with distribution maps, etc.), "Raptor Ecology" (with interesting data on guilds and communities), "Raptors as Predators" (with tables showing food habits, diagrams showing hunting techniques, etc.), "Raptor Reproduction" (with considerable data drawn from Olsen's previously published work), "The Healthy Raptor" (with data on pesticides, parasites, etc.), "Studying Raptors" (giving techniques and methods that have been tried and tested in Australia and elsewhere), "Raptors And Humans" (with a discussion on rehabilitation, etc.), and "Conservation and Raptors." The last two chapters are particularly timely considering current interests. The chapter on conservation describes such topics as general threats to raptors, some specific initiatives in Australia (using a great photo from a video of peregrine falcons [*Falco peregrinus*] feeding young at an artificial nest box on the 33rd story of a downtown Melbourne skyscraper), the problems of importing raptors and research and education.

All of the chapters present information that one

ıs not likely to find elsewhere; the data are not just a rehash of other published books and works. Although the data are aimed mainly at an Australian audience, examples from raptors around the world are used to illustrate points. In fact, a touchy point for some people from the southern hemisphere is that too great a reliance has been placed on raptor studies from North America and Europe, where ecological conditions, and thus findings, may not be relevant to what occurs in the southern continents. Very clearly, I found the book to be an exceptional contribution; thus, there is no reason to dwell on the minor shortcomings and the few errors that exist. Two items stand out as a distraction, however. The color fidelity of the fly cover, showing a brown goshawk (*Accipiter fasciatus*) feeding on a rabbit, is very poor (the photo has an intense red wash). The same picture is reproduced on page 90, and there the color fidelity is good. The highlighted text boxes (e.g., "Maternal Hormones in Eggs?," "DNA Hybridisation," "Fertilisation and Embryonic Development") have a distracting feather pattern, seemingly taken from the drawing of an outstretched wedge-tailed eagle (*Aquila audax*) wing, providing a background motif. A simple uniform unpatterned background color would seem to have been a better choice.

The author has used some nice tables and charts, many of which appear for the first time in this book. To mention several: a classification comparing her data (surely incorporating her feather protein analysis) with DNA-DNA hybridization and another classical well-accepted system; estimates of breeding populations of some species in various Australian states and trends in changes in numbers of Australian species; diagrams of hunting techniques in both *Falco* and *Accipiter*, niche partitioning among *Accipiter* on three continents (patterned after a similar graph in Leslie Brown's *Birds of Prey: Their Biology and Ecology*, 1976); maps showing geographic variation in clutch size and egg volume; and tables showing morphological variation and character displacement in beak size of several species. As an indication of the wealth and frequency

of graphic material, I opened the book randomly to page 94, contained in the chapter "Raptors as Predators," and looked at the following six pages: page 94, photos showing a spotted harrier (*Circus assimilis*) quartering over bush and a peregrine striking a quail, table showing various search and attack techniques used by different Australian raptors; page 95, photo sequence of brown falcon (*Falco berigora*) catching prey, photo of flock of black kites (*Milvus migrans*) soaring, photo of cooperative hunting by peregrines; page 96, photo of wedge-tailed eagles squabbling over carcass, photo of brown falcon crouching over prey; page 97, photo of a pair of grey falcons (*Falco hypoleucos*) cooperatively feeding, photo of peregrine male feeding its mate; page 98, table suggesting categories of social foraging using Australian species as examples, photo of osprey (*Pandion haliaetus*) rising from water with fish; and page 99, table of hunting success of six species of Australian raptors that feed on four different prey categories, table of hunting success of six species depicted by sex and age.

The numerous photographs were provided mainly by Nicholas Birks, who may be Australia's finest contemporary wildlife photographer. While I did not make a detailed evaluation of all of the photographs, their frequency seems to be weighted in favor of *Falco* and *Aquila*. Regardless, all of the photos illustrate critical aspects of raptor biology discussed in the particular chapter. For example, "The Healthy Raptor" contains photos showing broken eggs because of eggshell thinning from pesticide contamination, molting accipiters, grooming falcons, bathing eagles, flocking kites, and dozing (roosting) falcons. Some of the finest raptor photographs I have seen appear in this book. Additionally, some excellent pencil sketches by Humphrey Price-Jones appear on the inside covers and here and there throughout the book. My recommendation about the book as something valuable for scientists and general raptor enthusiasts has been stated and implied several times, and at the price you can't go wrong.—**Clayton M. White, Department of Zoology, Brigham Young University, Provo, UT 84602 U.S.A.**

THESIS ABSTRACT

BALD EAGLE NESTING ECOLOGY AND HABITAT USE: LAKE McDONALD,
GLACIER NATIONAL PARK, MONTANA

Management of bald eagle (*Haliaeetus leucocephalus*) breeding areas requires information on nesting chronology and habitat use. I documented nesting activity, perch tree and roost site use at Lake McDonald in Glacier National Park, Montana from 10 January 1986–13 August 1987. In April 1986, after 18 d of incubation, the nest failed as an indirect result of food stress. Female mate replacement occurred in April 1987, but no egg was produced.

In March 1986, I equipped the adult male eagle with a radiotransmitter and telemetry locations were used to determine defended territory (12.6 sq km), nesting home range (235 sq km) and regional range (over 3000 sq km), and to document nearly 3000 perch sites. Seasonal maps show the male eagle's relative frequency of specific perch site use. Foraging perches at Lake McDonald were concentrated at inlets, points and shallow bays. Long-range movements to southeastern British Columbia (144 km from Lake McDonald) were documented in summers 1986 and 1987. The Primary Use Zone, the area where the eagles did most of their foraging and loafing, was mapped based on 3266 hr of observation. Roost sites were in proximity to the nest site during nesting and to foraging sites during nonnesting.

Threats to the resident pair include human disturbance, food stress, habitat loss, collision with vehicles or trains, shooting, poisoning and trapping. All five stream inlets on the territory are influenced by human activity and facilities. Human disturbance compounds the negative effects of the marginal prey base at Lake McDonald. Recent removal of old-growth vegetation along the lakeshore and at Lake McDonald Lodge has accelerated habitat deterioration. Site-specific management recommendations stress reducing human disturbances at foraging sites and maintaining old-growth and screening vegetation at nest, forage and roost sites. Reduction of human disturbance and an increase in foraging opportunities at the head of Lake McDonald during the critical nesting season (1 Mar–15 May) and during autumn kokanee salmon (*Oncorhynchus nerka*) spawning runs (1 Nov–31 Dec) may improve bald eagle productivity at this breeding area.—**Richard E. Yates. 1989. M.S. thesis, Department of Wildlife Biology, University of Montana, Missoula, MT 59801 U.S.A. Present address: U.S. National Park Service, Glacier National Park, West Glacier, MT 59936 U.S.A.**

JOURNAL OF RAPTOR RESEARCH
INFORMATION FOR CONTRIBUTORS

The *Journal of Raptor Research* (JRR) publishes original research reports and review articles about the biology of diurnal and nocturnal birds of prey. All submissions must be in English, but contributions from anywhere in the world are welcome. Manuscripts are considered with the understanding that they have not been published, submitted, or accepted for publication elsewhere. Manuscripts are subjected to peer review for evaluation of their significance and soundness, and edited to improve communication between authors and readers. Decisions of the editor are final.

Material is published as feature articles, short communications (usually not longer than two printed pages), and letters (see recent issue of the JRR for examples). In addition to scholarly papers, the JRR publishes noncommercial ornithological news, thesis abstracts, announcements, and requests for assistance. Announcements that carry a deadline should be submitted at least six months in advance to ensure sufficient time for publication and response.

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INDEX TO VOLUME 30

BY ELISE VERNON SCHMIDT

The index includes references to genera, species, common names, key words and authors. Reference is also made to book reviews, dissertation and thesis abstracts, letters, reviewers, and instructions to authors. Taxa other than raptors are included where referenced by authors.

THE JOURNAL OF RAPTOR RESEARCH

CONTENTS FOR VOLUME 30, 1996

NUMBER 3

NUMBER 4

The Journal of Raptor Research is distributed quarterly to all current members. Original manuscripts dealing with the biology and conservation of diurnal and nocturnal birds of prey are welcomed from throughout the world, but must be written in English. Submissions can be in the form of research articles, letters to the editor, thesis abstracts and book reviews. Contributors should submit a typewritten original and three copies to the Editor. All submissions must be typewritten and double-spaced on one side of 216 × 278 mm (8½ × 11 in.) or standard international, white, bond paper, with 25 mm (1 in.) margins. The cover page should contain a title, the author's full name(s) and address(es). Name and address should be centered on the cover page. If the current address is different, indicate this via a footnote. A short version of the title, not exceeding 35 characters, should be provided for a running head. An abstract of about 250 words should accompany all research articles on a separate page.

Tables, one to a page, should be double-spaced throughout and be assigned consecutive Arabic numerals. Collect all figure legends on a separate page. Each illustration should be centered on a single page and be no smaller than final size and no larger than twice final size. The name of the author(s) and figure number, assigned consecutively using Arabic numerals, should be pencilled on the back of each figure.

Names for birds should follow the A.O.U. Checklist of North American Birds (6th ed., 1983) or another authoritative source for other regions. Subspecific identification should be cited only when pertinent to the material presented. Metric units should be used for all measurements. Use the 24-hour clock (e.g., 0830 H and 2030 H) and "continental" dating (e.g., 1 January 1990).

Refer to a recent issue of the journal for details in format. Explicit instructions and publication policy are outlined in "Information for contributors," *J. Raptor Res.*, Vol. 27(4), and are available from the editor.

1997 ANNUAL MEETING

The Raptor Research Foundation, Inc. 1997 annual meeting will be hosted by Georgia Southern University and will be held October 30 through November 2 at the Marriott Riverfront in Savannah, Georgia. Details about the meeting and a call for papers will be mailed to Foundation members in the spring of 1997. For more information, contact Michelle Pittman (912/681-5555, e-mail: meeden@gsvms2.cc.gasou.edu) or Steve Hein (912/681-0831) at Georgia Southern University.

RAPTOR RESEARCH FOUNDATION, INC., AWARDS
Recognition for Significant Contributions[1]

The **Dean Amadon Award** recognizes an individual who has made significant contributions in the field of systematics or distribution of raptors. Contact: **Dr. Clayton White, 161 WIDB, Department of Zoology, Brigham Young University, Provo, UT 84602 U.S.A.** Deadline August 15.

The **Tom Cade Award** recognizes an individual who has made significant advances in the area of captive propagation and reintroduction of raptors. Contact: **Dr. Brian Walton, Predatory Bird Research Group, Lower Quarry, University of California, Santa Cruz, CA 95064 U.S.A.** Deadline: August 15.

The **Fran and Frederick Hamerstrom Award** recognizes an individual who has contributed significantly to the understanding of raptor ecology and natural history. Contact: **Dr. David E. Andersen, Department of Fisheries and Wildlife, 200 Hodson Hall, 1980 Folwell Avenue, University of Minnesota, St. Paul, MN 55108 U.S.A.** Deadline: August 15.

Recognition and Travel Assistance

The **James R. Koplin Travel Award** is given to a student who is the senior author of the paper to be presented at the meeting for which travel funds are requested. Contact: **Dr. Petra Wood, West Virginia Cooperative Fish and Wildlife Research Unit, P.O. Box 6125, Percival Hall, Room 333, Morgantown, WV 26506-6125 U.S.A.** Deadline: established for conference paper abstracts.

The **William C. Andersen Memorial Award** is given to the student who presents the best paper at the annual Raptor Research Foundation Meeting. Contact: **Ms. Laurie Goodrich, Hawk Mountain Sanctuary, Rural Route 2, Box 191, Kempton, PA 19529-9449 U.S.A.** Deadline: Deadline established for meeting paper abstracts.

Grants[2]

The **Stephen R. Tully Memorial Grant** for $500 is given to support research, management and conservation of raptors, especially to students and amateurs with limited access to alternative funding. Contact: **Dr. Kimberly Titus, Alaska Division of Wildlife Conservation, P.O. Box 20, Douglas, AK 99824 U.S.A.** Deadline: September 10.

The **Leslie Brown Memorial Grant** for $500–$1,000 is given to support research and/or the dissemination of information on raptors, especially to individuals carrying out work in Africa. Contact: **Dr. Jeffrey L. Lincer, Sweetwater Environmental Biologists, Inc., 3838 Camino del Rio North, Suite 270, San Diego, CA 92108 U.S.A.** Deadline: September 15.

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[1] Nominations should include: (1) the name, title and address of both nominee and nominator, (2) the names of three persons qualified to evaluate the nominee's scientific contribution, (3) a brief (one page) summary of the scientific contribution of the nominee.

[2] Send 5 copies of a proposal (≤5 pages) describing the applicant's background, study goals and methods, anticipated budget, and other funding.